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DESCRIPTION AND SAMPLING OF THE ROCKS
OF THE PHOSPHORIA FORMATION

by

V. E. McKelvey

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DESCRIPTION AND SAMPLING OF THE ROCKS OF THE PHOSPHORIA FORMATION

by

V. E. McKelvey

During the coming few years the phosphatic shale member of the Phosphoria formation will be sampled and described at many localities in Montana, Idaho, Wyoming, and Utah. Because the samples and descriptions will be collected and prepared by many different geologists, the necessary high degree of uniformity in terminology, completeness of descriptions and standards of sampling will not be achieved unless the participating geologists adopt nearly uniform procedures.

The procedures herein recommended for sampling, field description of rocks and preparation of stratigraphic sections will produce the desired uniformity in the data if adopted by those engaged in the phosphate work. As they are based upon some years experience, not only of my own, but of others working on the problem, 1/ they are believed to be in usuble form. Nevertheless, additional experience will lead to their further improvement and the procedures described will be changed as further experience requires. Though I ask that the recommended procedures be used throughout the western phosphate work, at the same time I hope that the geologists using them will make such suggestions for their improvement as seem appropriate and will record such additional data or adopt such other procedures as seem important.

Additional procedures to standardize interpretation of chemical analyses, routine petrographic study, and calculation of reserves will be presented later.

SPACING OF INTERSECTIONS

The goal of the present investigation is to sample the Phosphoria formation at intervals of 3 to 6 miles, or at least at one or two localities in each township containing outcrops of the formation, over the whole of the western field. As major changes in lithology of most beds of the Phosphoria generally take place at intervals of more than 10 miles (in fact many units are in places lithologically uniform over tens or scores of miles), such a spacing will in most places permit the correlation of lithologic units from one locality to another and thus provide partial basis for computing reserves of the "inferred" class.

1/ Many of the procedures described herein have been suggested by other Survey geologists, expecially W. W. Rubey, L. E. Smith, R. M. Campbell, W. P. Huleatt, R. A. Weeks, and M. R. Klepper.

Structural or stratigraphic conditions may require a wider spacing of intersections in certain areas. In such cases an effort should be made to obtain at least two, and preferably three, intersections in a given area, so as to provide some basis for checking results, even if the intersection must be spaced at intervals of less than 3 miles.

TRENCHING

Because natural exposures of the phosphatic portions of the Phosphoria are rare over most of the region, because no suitable method is yet available for satisfactory coring the phosphatic portions, and because the cost of tunneling is prohibitively high, the phosphatic beds in most places must be sampled in trenches.

Depth required

Even trenching is costly and often does not produce a satisfactory exposure for over much of the region the overburden is 5 to more than 30 feet thick and the bedrock below is physically and chemically weathered to a greater or lesser degree. It is often difficult to tell whether bedrock is exposed throughout a trench. Some beds, like certain hard limestones, are more resistant to weathering than others and may appear relatively fresh in the trench wall at depths where less resistant interbedded mudstones are so weathered as to have lost all bedrock characteristics. Care must therefore be taken to see that the trench yields the best possible exposure. In many places this will mean digging the trench to the greatest depth possible--to the point, in other words, where further deepening is not possible because the spoil cannot be removed or because the bedrock is too hard to permit further excavation without resorting to blasting. True bedrock may often be distinguished from soil or mantle by presence of bedding, relative hardness, accordance of dips with those over the rest of the trench (weathered rock has a tendency to slump downslope). Generally if there is any doubt as to whether the bedrock is exposed, it is not exposed, and the trench should be deepened if possible.

Topographic setting and manner of excavation

Trenches can be excavated by hand or by bulldozer (preferably one equivalent in size to a D7 or D8, and equipped with an angle dozer). The bulldozer-trench is preferred because it can be dug to a greater depth and provides a wider exposure. The great depth attainable (over 30 feet by bulldozer compared to a depth of about 12 feet practical to attain by hand methods) greatly increases chances of exposing relatively fresh bedrock, and the wider exposure provided may reveal irregularities in stratigraphy or structure not ordinarily seen in the limited exposures of a hand trench. In addition, the roomyness of the bulldozer-trench makes for much more efficient and accurate description and sampling than is possible in the cramped quarters of a hand trench.

Bulldozer-trenches should be dug on the horizontal or as close to the horizontal as possible, for generally irregularities in the bedrock surface are of such magnitude that it is necessary to gouge out deep holes in parts of the trench; if the trench is not begun on the horizontal, the uphill slope of these holes may become too steep (i.e. more than about 25 degrees) for the bulldozer to negotiate. The trenches should be located nearly perpendicular to the strike of the rocks and best results will be obtained if it is dug along a steep (25 degrees or more) slope, both because the thickness of cover (and the depth of weathering) is likely to be less on such a slope and because the bulldozer operator can remove the waste more efficiently. A convex slope generally is not as favorable for a trench site as a concave one and if the slope is concave the trench should be located well above the base, if not actually at or near the top. If the slope is concave in the horizontal plane (as is often the case where a weak formation lies between two resistant ones and where all are steeply inclined) thick talus may be expected at one or both ends of the trench and it is best to choose a level on the slope at which the concavity is at a minimum.

Hand trenches may be required in areas not accessible to a bulldozer or when, as is often the case now, a bulldozer cannot be hired, or when it is necessary to expose gently dipping beds. Like bulldozer trenches, hand trenches will be most successful if located on or at the edge of a steep slope (in sharply dissected areas of high and steep slopes bedrock may be closest to the surface at the very crests of the ridges) but of course the slope of the hand trench itself can be steeply inclined. Where a hand trench is to be dug down slope, excavation should be begun at the top of the slope, so as to prevent accidental backfilling; the waste should be discarded in such a way, of course, that it will not need to be rehandled as the trench progresses.

Hand trenches cannot be dug efficiently on most heavily wooded slopes partly because of the time consumed in cutting down trees and roots, but also because the overburden is generally too deep (the depth of the soil cover is attested to by the very presence of the forest). The trees are not an obstacle to a bulldozer, however, and in fact wooded slopes are apt to be good bulldozer sites, for though a few feet of soil is required for the growth of the forest, the latter helps stabilize the slope and prevents movement of talus, so that bedrock is often within 20-30 feet of the surface.

In locating either a hand trench or a bulldozer trench it is well to choose a site which either contains a few patches of natural outcrop of the phosphatic shale, or abundant phosphatic shale float, or black soil, or, if spots containing none of these can be found, a site at least near good outcrops of the adjacent formations.

Both hand trenches and bulldozer trenches are apt to cave, especially during and shortly after excavation, a thaw, or a soaking rain. A hard hat should be worn at all times when working in the trench and one eye and both ears kept trained on the slope overhead. Slide danger is greatest in bulldozer trenches exposing coarse talus. Caving can be minimized by cutting the uphill bank on a slope of about 60 degrees rather than vertical intervals of 10 or 15 feet.

It is sometimes not possible to expose the complete section in one continuous trench so that the section must be pieced together from two or more trenches. A section so measured is entirely adequate but the trenches must overlap stratigraphically and at least one key bed must be exposed in the overlapped portions.

Trench records

Two records will be prepared on each trench, one showing the location of the trench and the relation of the portion exposed to the overlying and underlying formations (p. 5) and the other showing the time required to complete the various phases of work on the trench, including digging, sampling, description, (p. 6) etc. A sketch (on a scale of 50 feet to the inch) showing the trench plan, accompanied by a vertical section showing its depth and the depth to bedrock at several points along the trench should also be prepared.

SAMPLING

Portion of Phosphoria formation to be sampled

The full thickness of the phosphatic shale member should be sampled at every locality, including beds that may not appear phosphatic as well as those obviously phosphatic. Where the phosphatic shale member is not a clearly defined unit, the entire phosphatic and/or dark colored part of the Phosphoria formation should be sampled; or stated differently, only the light colored limestone, quartzite, and chert sequences near the top and at the base of the Phosphoria should be excluded. Phosphatic zones within and especially above the Rex chert should be sampled also, but it will not be necessary to sample the apparently non-phosphatic beds of the Rex unless they lie between phosphatic beds and are less than the combined thickness of the adjacent phosphatic beds.

The limits of each unit chosen for sampling should be marked by driving a ten-penny nail at the appropriate spot in the trench wall at the top and base of the unit. The number of the sample should be written on a shipping tag placed on the nail at the stratigraphic base of each sample.

State: Wyoming County: Lincoln Date: 7-1-48 to 7-16-48

Trench name and number: Rock Creek Geologist: RMC RPS

T. 23 N., R. 119 W., SE¼ Sec. 19 - 5 miles N of Nugget, Wyo.

Structure: East Limb of North Pitching Dempsey anticline

Length of trench: 186 feet Av. depth: 14 feet Its strike: N 85°W

Time required to dig: 20 hrs. B.D. Time required to sample: 80 hrs.
36 hrs. labor

Samples and beds numbered from bottom to top.
Sample numbers: 542-RMC to 600-RMC, 1068-DFD to 1148-DFD,
1520-RPS to 1554-RPS

Thickness of beds exposed: 158.8' Strike: N 15°E Dip: 75°E

Total thickness of phosphatic shale member: 132.4'

Description of uppermost Wells formation. Rock name: Limestone

Thickness: 14.3 exposed Strike: N 18°E Dip: 75°E

Stratigraphic distance from end of trench to highest Wells outcrop: 58'

Nature of contact between Wells and Phosphoria formations: gradational

Distinctive beds within 100' of bottom of phosphatic shale: 2' cherty white ls bed 72 feet stratigraphically below base of phos. shale.

Fossiliferous horizons: 0.5' bed of highly fossiliferous ls, 10' below phos. shale.

Description of Rex. Rock name: Chert and cherty limestone

Thickness: 12.1 exposed Strike: N 15°E Dip: 75°E

Stratigraphic distance from end of trench to lowest outcrop of Rex: 42'

Nature of contact between Rex and phosphatic shale members: sharp to conformable.

Distinctive beds within 100' of top of phosphatic shale: 0.05' oolitic chert layers 4' and 10' above phos. shale

Fossiliferous horizons: 2' gastropod layer 54' above phos. shale.

TIME RECORD

Trench name:

Date	Transportation		Preparation		Supervision		Description of beds		Sampling		Remarks
	Name	Hrs.	Name	Hrs.	Name	Hrs.	Name	Hrs.	Name	Hrs.	
7-1-48	Hunziker	1									* moving Bulldozer to Site
	B.D. + Hunziker	* 4	Hunziker	** 4	Sheldon	8					** Starting Trench
7-2-48	Sheldon	½	Hunziker	8	Sheldon	7½					Digging Trench
	Hunziker	1½									
7-3-48	Rest	½	Rigby	8							
	Hunziker	1½	Hunziker	8	Campbell	4½	Campbell	4			Digging Trench
7-5-48	All	½ ea	Rigby	7½			Campbell	7½	Sheldon	7½	
7-6-48	All	½ ea	Rigby	3½			Campbell	7½	Sheldon	7½	
							Davidson	7½	Rigby	4	
7-7-48	All	½ ea	Rigby	3½			Campbell	7½	Rigby	4	
							Sheldon	3½	Sheldon	4	
7-8-48	All	½ ea	Rigby	7½			Campbell	7½	Sheldon	7½	
							Davidson	7½			
7-9-48	All	½ ea	Rigby	3½			Campbell	7½	Sheldon	7½	
							Davidson	7½	Rigby	4	
7-12-48	All	½ ea					Campbell	7½	Rigby	7½	
							Davidson	7½			
							Sheldon	7½			
7-13-48	All	½ ea					Davidson	7½	Rigby	7½	
							Sheldon	7½			
7-14-48	All	½ ea					* Campbell	7½	Sheldon	7½	* Preparation of sketch
							Davidson	7½			Map of Trench location
7-15-48	All	½ ea					Campbell	3½	Sheldon	7½	Preparation of sketch map
7-16-48	All	½ ea					Davidson	2½	Sheldon	5	
							Sheldon	1½	Rigby	1	
	Bulldozer +						Campbell	60			** Rigby 4½ hr. Campbell 4½ hr.
	Hunziker	4	Hunziker	20	Sheldon	16	Davidson	48	Sheldon	60	Sheldon 5½ hr. Davidson 3½ hr.
	Rest **	22	Rigby	36	Campbell	8	Sheldon	20	Rigby	20	Hunziker 4 hr.
Totals: (Hrs.)		26		56		24		128		80	TOTAL HOURS: 314
							$76.20				Rigby: 0.94/hr. B.D. 10.00/hr.
ost	$40.00		$200.00		$16.64		60.96		$62.56		Sheldon + Hunziker 1.04/hr.
	24.25		33.48		10.17		20.80		18.60		Campbell + Davidson 1.27/hr.
Totals: (Cost)	$64.25		$233.48		$26.81		$157.96		$81.16		TOTAL COST: $563.66

Thickness of units to be sampled

Separate samples should be collected from each lithologic unit 0.5 foot or more in thickness or from smaller units which occur as partings between lithologic units which are 0.5 foot or more thick; lithologic units less than 0.5 foot in thickness occurring in sequence can be grouped together and a thickness of 0.5-1.0 foot included in one sample. Lithologic units 5 feet or more in thickness should be divided into two or more parts, so that no more than 5 feet is included in one sample.

Nature and size of sample

Each sample should be cut from a channel or bench 3-4 inches deep and 6-8 inches wide, which will produce 15 to 40 pounds of rock per foot of channel; the dimensions of the channel should be larger in rocks jointed in such a manner that the edges of a channel cut in them are jagged or irregular and can be smaller in rocks in which a relatively smooth-walled channel can be cut. The channel likewise should be larger where a sequence of samples is to be cut from thin units than where they are cut from thick units. No sample should weigh less than 12 pounds, regardless of how thin a unit it represents. Special care should be taken to see that the sample is representative of the unit from which it is taken. The channel can either be normal to the strike and dip or at an angle to either the strike or dip, depending upon the orientation of the trench with respect to the structure, as well as the type and degree of development of the jointing. The channel must be cut on a single plane, whatever its orientation may be, so as to obtain equal parts stratigraphically of the entire unit. If this cannot be done, the unit should be further subdivided into parts in each of which a channel and a separate sample can be cut in a single plane.

Numbering of samples

Beginning during the '48 season, samples will be numbered consecutively, beginning with No. 1 and extending on as high as may be necessary. Each party will be alloted a series of numbers for use during each season. Each sample will be further distinguished by the initials of the man who collected it, so that the sample number will read, for example, 920RMC or 921 RAH. Hand specimens should be given the same serial number as the channel sample but accompanied also by a letter, as: 920a RMC.

Each group of samples from a single locality will be assigned a lot number when it is received for crushing in Montpelier.

Labelling

Each sample should be labelled in three places: 1) with a soft pencil on the outside of the sample sack itself, 2) in pencil and in ink on a shipping tag tied to the draw strings of the sack, and 3) in pencil and in ink on a paper label which is rolled into a tube, then bent in half and placed inside the sack. To protect the inside label from loss or damage, the sack should be tied just above the rock and also at the top; the label is then

placed in the pocket between the two ties. If the sack is too full to be tied in this way, the label should be placed in the neck of the sack at the tie-string and, after carefully folding the sack around it, tied so that the label will be held securely in the fold at the neck of the sack.

Crushing and quartering

Ordinarily each sample will be brought into Montpelier, Idaho, where it will be mechanically crushed to minus one-quarter inch mesh and split to 10 pounds.

If the trench is far from a road it may not be practical to transport samples away from the trench without crushing and splitting. In this case the rock fragments should be broken to minus one-quarter inch size, coned and quartered on a sampling canvas or in a Jones splitter until reduced to 10 pounds (in coning and quartering opposite quarters of the cone are retained and re-coned and re-quartered until reduced to the desired size).

Hand specimens

A hand specimen, which will be used both for megascopic and microscopic examination, should be collected from each unit sampled. Its label (on outside of envelope) should show the distance above the base of the unit from which it came as well as the unit number, the formation and geographic location, as in the following example:

Location: Big Sheep Gulch

Formation: Phosphatic shale member,
Phosphoria formation

Unit No.: P-26

Sample No.: 831CEW

Distance above base: 0.8 feet

Disposition of samples

Though most of the geologists engaged in work on western phosphate will not be concerned with the actual shipment of the samples beyond removal from the trench site, it may help all to know what is done with the samples and what parts are saved for study.

After coarse crushing and quartering, (to 10 pounds of minus one-quarter inch mesh material) all samples are shipped to our chemical laboratory in Denver. There each sample is split into two parts, one of which is reduced to about $3\frac{1}{2}$ pounds (one quart) and stored without further grinding; the other part is reduced to about $3\frac{1}{2}$ pounds and ground to minus 20 mesh; part (about 300-400 grams) of the minus 20 mesh material is cut out and ground to

minus 80 mesh and the remainder of the minus 20 mesh sample is stored without further treatment. The minus 80 mesh material is shipped for chemical analysis to the laboratories of either the Tennessee Valley Authority or the Bureau of Mines. Large amounts of both minus one-quarter inch mesh and minus 20 mesh material are therefore available for petrographic study or other analysis (including density determinations, spectrochemical analysis, heavy mineral studies, etc.).

Of the original sample, that portion remaining after reduction of our sample to 10 pounds is shipped to the Albany laboratory of the Bureau of Mines for metallurgical study.

Sample records

The attached record (p.10) (showing lot number, field sample number, locality, date cut, type, weight, map reference, type of rock and formation from which cut) is to be kept primarily for the benefit of the Denver chemical laboratory. It should be made out in the field in duplicate and the samples entered in stratigraphic order from oldest to youngest from bottom to top of the page.

A check list (p. 11) will also be kept of samples from each locality. This list is to show the date each sample is cut, when it is received in Montpelier for crushing, when it is crushed, and when it is shipped. This list is to be made up at the trench at the time the samples are cut and then delivered with the samples to the crushing lab in Montpelier.

Each geologist should keep a record in his own notebook of the sample numbers he has used, the date they were described, and the locality from which they come. Each sampler should keep a similar record.

These various sample records, of which there seem to be a multitude, have been found necessary to help prevent duplication and loss of samples. The records themselves will of course not prevent duplication or loss, though they will help. It will be the responsibility of each party chief to see that each sample is properly numbered and handled, that no number is used twice, that none of these assigned to him are omitted, and that no samples are lost.

ROCK DESCRIPTION

The field description of the rocks of the phosphatic shale is of special importance because 1) many of the beds, if properly described, can be correlated over great distances, and 2) the lithology is of great interest to those concerned with mining and processing the rock. Our object on the one hand is therefore to achieve in words and figures what the portrait artist does with lines and shading--each bed may be compared to a face which must be sketched in such a way that the same face can be recognized again even if seen from another angle. On the other hand, our aim is to describe the rocks in terms such that mining and metallurgical engineers can predict how the rocks will react under certain conditions. Both objectives require a consistent use of terminology.

sieve 80 mesh and the remainder of the minus 80 mesh sample is saved without further treatment. The minus 80 mesh material is shipped for chemical analysis to the laboratories of either the Tennessee Valley Authority or the Bureau of Mines. Large sample splits of both one-quarter inch and the minus 80 mesh materials are therefore available for petrographic study or other analyses (including density determinations, spectrochemical analysis, heavy mineral studies, etc.).

Of the original sample, that portion remaining after reduction of the sample to 10 pounds is shipped to the Albany laboratory of the Bureau of Mines for metallurgical study.

Sample Records

The attached record (p.10) showing lot number, field sample number, location, [illegible] type, weight, and references, type of [illegible] form which will have to be kept primarily for the benefit of the [illegible] laboratory. It should be made out in the field in duplicate and the original shipped if [illegible] under separate cover [illegible] of the sack.

A sample list (p. 11) will also be kept of samples [illegible] quantity. This list is to show the date each sample is cut, when it is received by [illegible] for crushing, when it is crushed, and when it is analyzed. This list is to be made up at [illegible] at the time the samples are [illegible] delivered with the samples to the crushing lab in Montpelier.

Each geologist should keep a record in his own notebook of the sample numbers he has cut, the date they were cut, and the [illegible] they were [illegible]. Each sampler should keep a similar record.

These various sample records, of which there seem to be a multitude, have been found necessary to help prevent duplication and loss of samples. The [illegible] will of course not prevent duplication or loss, but they will help. It will be the responsibility of each [illegible] to see that each sample is properly numbered and handled, [illegible]

ROCK DESCRIPTION

The field description of the rocks in the phosphatic shale is of [illegible] importance because [illegible] many of the beds, if properly described, can be correlated [illegible] and if the lithology is [illegible] with cutting and preserving the logs. The object of the [illegible] to describe in words and figures what the [illegible] [illegible] and which may be [illegible] in a way that the same [illegible] can be recognized [illegible]. On the other hand, [illegible] and metallurgical engineers [illegible] under present conditions. Both objectives [illegible] description.

Lot No. 1242 SAMPLE DATA Sheet 2 of 14

Geologist: R.M. CAMPBELL, D.F. DAVIDSON Sampler: R.P. SHELDON

Denver Serial No.	Field Sample No.	Locality	Date	Type *	Map Ref.				Material	(over) Formation, etc.
	568-RMC-	Rock Creek, Wyoming	6-2-48	a					Mudstone	Phosphatic shale member. Phosphoria formation
	569-RMC-	"	"	a					Phosphate rock	"
	570-RMC-	"	"	a					Mudstone	"
	1068-DFD-	"		a					Mudstone Phosphatic	"
	1069-DFD-	"		a					Limestone Concretion	"
	1070-DFD-	"		a					Mudstone, calcareous	"
	1071-DFD-	"		a					Phosphate rock	"
	1072-DFD-	"		a					Phosphate rock	"
	1073-DFD-	"		a					phosphate rock	"
	1074-DFD-	"		a					Phosphate rock	"

*Type: a)-channel, b)-chip, c)-grab, d)-placer, 3)-mill head, f)-millconct, g)-middling, h)-mill tail, i)-refinery product, j)-drill core, k) ill sludge.

Page____ of ____

Trench Name:
Sample Numbers

Party Chief:
B/L: I-_______

SAMPLE NUMBER		CUT		DATE RECEIVED FOR CRUSHING	WEIGHT	DATE CRUSHED	DATE SHIPPED TO DENVER	DATE SHIPPED TO ALBANY	REMARKS
(No.)	(Logger)	Date	Sampler						

Classification of the rocks of the Phosphoria formation 2/

Rocks of the Phosphoria and adjacent formations consist of mixtures of three types of materials; chemical sediments (dominantly phosphate, calcite, dolomite, and chert but locally including minor amounts of pyrite or marcasite, gypsum and glauconite); detritus (quartz, clay, mica, feldspar, etc.); and attritus (i.e. organic matter). These three types of materials might be envisioned as occupying the corners of a ternary diagram, on which points representing the composition of most Phosphoria rocks would be scattered over the interior of the diagram and few, if any, would fall at the corners. Most of these materials are of silt- or clay-size, though sand-sized particles do occur in parts of the field. In addition some of the chemical particles (expecially the phosphates) are structurally aggregated into oolites, pisolites, or similar forms which give a coarse-textured appearance. Except for some of the cementing material, which may have been of secondary crystallization, all of the sediments are of mechanical deposition--even the chemical precipitates such as calcite and phosphate were deposited, once they were precipitated from solution, in the same manner and were subjected to the same amount and kind of reworking by bottom currents as the detritus and attritus.

For purposes of classification, organic matter, which is difficult to evaluate quantitatively even in the laboratory, much less in the field, may be disregarded and the sediments considered to be of two types: chemical and detrital. The rock name of the chemical sediments will be derived from the name of the mineral forming more than 50 percent of the rock 3/ (or forming the dominant mineral if other minerals compose more than 50 percent of the rock) and will be modified by adjectives representing minerals which make up more than 20 percent of the rock. The rock name of the detrital sediments will be based upon texture and qualified by adjectives in the same way as the chemical rocks. Because the differentiation of the finest-grained detrital rocks is too difficult to attempt in the field, the siltstones and claystones generally will be grouped in the general term mudstone, which is used without regard to the physical behavior of the rock on repeated wetting and drying.

Classing the rocks in this way, the Phosphoria formation and adjacent formations contain six pure rock types: phosphate rock, limestone, dolomite, chert, mudstone and sandstone; 36 types composed principally of mixtures of

---

2/ The reader should study the recent series of articles by F. J. Pettijohn, R. R. Shrock, and P. D. Krynine published in the Journal of Geology, vol. 56, No. 2 in March 1948, to acquire a thorough understanding of the problems of classification of sedimentary rocks.

3/ The phosphate mineral is francolite or collophane, which is $10CaO.3P_2O_5.CaF.CO_2$.

two minerals, as phosphatic limestone, dolomitic mudstone, cherty phosphate rock, argillaceous sandstone, etc.: and 216 possible rock types in which three minerals each occur in amounts of more than 20 percent of the rock. Generally it will not be possible to differentiate the three-mineral rock types in the field and for practical purposes we may consider that we are dealing with the 36 types in which two minerals are dominant.

Attention should be called to the fact this classification eliminates certain rock names formerly in common use--shale (which where rigorously defined consisted of a fine-grained, fissile, detrital rock) oolite and pisolite. These names (which are based upon structural features) were abandoned prior to the 1947 field season with some misgivings, for they are easy to use in the field. Little difficulty was encountered, however, in describing the rocks without using these names. Though the term shale is discarded as a rock name, it may and will continue to be used as a formation name, as the "phosphatic shale member." The usage of the term "shale" in this sense for a group of fine-grained, thin-bedded--and not necessarily fissile--detrital rocks, is so firmly entrenched in stratigraphic nomenclature that it would be useless to try to change it, even if it were desirable to do so.

Features to be described

In addition to the rock name, which will ordinarily be the last step (at least mentally) in the description of a rock, a number of other features are to be described about each rock sampled. These include the thickness of the rock, its sub-texture (i.e. textural features not entering into the rock name), sub-composition, hardness, color, thickness of bedding, size and shape of fragments (naturally developed in the exposure because of jointing or fracturing of the rock) reaction to HCl, nature of contact with rock below, and any fossils which the rock may contain. A table (p. 14) has been prepared for the use of the geologist in describing these features, and the meaning of them can best be discussed in connection with instructions for the use of that table.

Use of table for field description of rocks

The table for field description of rocks is to be used for systematically recording observations on the rocks sampled. The description of each unit, as set up in the table, occupies two horizontal divisions; the upper line of each division is filled out according to the headings at the bottom of the page. An entry should be made in each space; if the feature called for in the heading is not present, a check mark line should be entered in place of the description, signifying that the feature was looked for but not found; if it was not checked or not determined, "n.c." or "n.d." should be entered in the appropriate space. Most features observable can be entered in the table under appropriate headings, but any observed feature that cannot be classified under one of the headings should be described on the back of the page. Such supplementary descriptions should be tied into those in the table by a circled footnote placed in the unit column.

Location: Big Elk Creek, Idaho
Formation: Phosphatic Shale member
Date: 7/4/48
Geologist: R. M. Campbell

<table>
<tr><th>Unit</th><th>Sample No.</th><th>Thickness</th><th>Dominant rock types</th><th>Nature of contact with unit below</th><th>Fossils</th><th colspan="3">Hand specimen (distance above base)</th></tr>
<tr><td>P-6</td><td>983 RMC</td><td>1.6</td><td>Phosphate rock $\overset{d}{a}$ Limestone</td><td>Sharp-plane</td><td>—</td><td colspan="3">b - 0.4' d - 1.4'
a - 0.1' c - 1.0'</td></tr>
<tr><td>Phos. rk 1Xb, 24</td><td>0.4</td><td>oolitic - 1/4-1; 1/2 mm.</td><td>arg.</td><td>med. hd.</td><td>black (N1)</td><td>0.1</td><td>chippy - 0.1</td><td>none</td></tr>
<tr><td>arg. ls. 15</td><td>0.4</td><td>crystalline - 1/2 mm.</td><td>—</td><td>hard</td><td>lt. brn. gr. (5YR 6/1)</td><td>0.1-0.2</td><td>blocky - 0.3</td><td>strong</td></tr>
<tr><td>phos. ms. 1Xb, 31</td><td>0.3</td><td>oolitic - 1/8-1/2; 1/4 min</td><td>micaceous</td><td>plastic</td><td>brn. bl. (10YR 2/2)</td><td>0.05</td><td>platy - 0.2</td><td>none</td></tr>
<tr><td>Phos. rk. 1Xb, 27</td><td>0.2</td><td>Pisolitic - 2-6; 3 mm.</td><td>—</td><td>crumbly</td><td>med. gr. (N6)</td><td>0.2</td><td>none</td><td>med</td></tr>
<tr><td>ls. 16</td><td>0.3</td><td>dense</td><td>cherty</td><td>hard</td><td>dk. gr. (N3)</td><td>0.3</td><td>blocky - 0.4</td><td>strong</td></tr>
<tr><td>in P5</td><td>n.s.</td><td>(0.0-0.5)</td><td>limestone lens</td><td>Sharp-beds bow around</td><td>cephalapods</td><td colspan="3">a - 0.3</td></tr>
<tr><td>limestone 13</td><td>0.0-0.5</td><td>crystalline - 1/2 mm.</td><td>—</td><td>hard</td><td>med. lt. gr. (N7)</td><td>none</td><td>none</td><td>mod</td></tr>
<tr><td colspan="3">lens is 1.6' long; base is 0.7' above base of P5.</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>P5</td><td>982 RMC</td><td>1.4-1.9; (1.4)</td><td>Mudstone: calcareous</td><td>gradational 0-1, 0.1</td><td>—</td><td colspan="3">a - 0.5'</td></tr>
<tr><td>cak ms 12</td><td>1.4-1.9; (1.4)</td><td>—</td><td>ferruginous</td><td>med. hd.</td><td>pale brown (5 YR 5/2)
(coatings strong brown (5 YR 4/8)</td><td>0.2-0.6</td><td>blocky - 0.4'</td><td>mod.</td></tr>
<tr><td>thickness varies because of lens</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><th>Rock names and symbol</th><th>Thickness</th><th>Sub-texture</th><th>Sub-composition</th><th>Hardness</th><th>Color</th><th>Thickness of bedding</th><th>Size and shape of fragments</th><th>Reaction to HCl</th></tr>
</table>

Unit

The term "unit" is used here, for want of a better term, for the rock sampled and/or described and its purpose is to define the stratigraphic succession of samples. Many of the units described will consist of a single bed of uniform lithology and bounded by a bedding plane at the top and base, but others may consist of several thin beds of different composition; or of layers of uniform character divided by one or more bedding planes; or of one layer containing a gradation in lithology. Begin the numbering of the units of each formation at each locality with the number 1 and number them from oldest to youngest; list the oldest unit at the bottom of each page and the youngest at the top and arrange the pages so that when the section is completed the page containing the youngest unit is at the top of the first page and the oldest at the bottom of the last page. Differentiate the units of one formation by the use of letter symbols preceding the number. Thus units of the Wells formation will be W1, W2, etc.; those of the phosphatic shale member will be P1, P2, etc.; those of the Rex, R1, R2; and those of the Dinwoody, D1, D2, etc.

Lenses or concretions described separately but occuring within another unit should be given the same unit number as the containing unit but preceded by the word "in." The thickness of such lenses or concretions should be placed in conspicuous parentheses, indicating that the thickness is not to be added to that of other units in obtaining the total thickness of the formation.

Sample number

The sample will represent the same thickness of rock as the unit (except where a lense or concretion within the unit is sampled separately) and will be designated by a field sample number, as previously described.

Thickness of the unit

The thickness should be measured at right angles to the bedding and expressed in feet and decimals of feet. If a range in thickness is observed, both the range and observed average should be stated, as 0.4--0.8'; (0.5').

Dominant rock types

As will be described in detail later, it is useful for many purposes to prepare an abstract of each section consisting of the unit, sample number, thickness, and the name or names of the bulk of the rocks represented. It is the latter that should be listed here.

Nature of contact with unit below

The nature of the basal contact of each unit should be described as sharp-plane, sharp-irregular (a condition which should be looked for but which will be found rarely), or gradational. If the lower contact is gradational, the width of the transition zone should be stated as, for example, 0.1, 0.2', which will be understood to mean that the transition zone is 0.3' thick and that 0.1' of it was included in the unit below and 0.2' in the overlying unit. Further details of the nature of the contact should be noted on the reverse of the sheet.

Fossils

The description of the size, type, abundance, orientation, external conditions, and spatial arrangements of the fossils will be made by a paleontologist, who will record his observations on a form similar to the one attached, (p. 17). For the geologists' part in the work, it will suffice generally to note which beds are fossiliferous, but if the exposure containing the fossiliferous beds is likely to cave in a short time, the geologist should make a collection and record such observations as he can about the abundance of the various types, etc.

Hand specimens

The distance above the base of the unit at which each specimen was collected should be shown in the table as well as on the specimen label. Each hand specimen should be marked with a red crayon line to indicate the plane in which a thin section is to be cut (usually normal to the bedding plane) and an "x" should be marked on the stratigraphic top of the sample.

Rock names and symbols

Many units will consist of interbedded layers of different lithologies and the lower division is ruled and organized in such a way that the description of individual layers can be easily carried across the page. The rock name generally will be one of the 36 types previously mentioned (additional names should be used of course to describe rocks of other materials such as gypsum, glauconite, etc., if found) and will consist of a noun supplemented by a compositional modifier when necessary.

The number of the symbol which will be used to graphically portray the rock on columnar sections and correlation charts should be shown beside the rock name. These symbols have been printed on waxed cellophane (similar to commercial Zip-a-Tone) and are shown on the attached explanation. Because the columnar sections generally will be plotted on a scale of 5 feet equals 1 inch, separate lithologic symbols should not be given for units less than 0.5 feet thick.

Thickness of beds

The thickness of individual beds separately described is to be shown in decimals of feet on the lower division. Where the unit sampled consists of only one bed, this figure will be the same, of course, as that given on the upper line.

Sub-texture

Under the heading "sub-texture" should be described such features of texture as do not enter into the rock name, as well as features of internal structure (i.e. oolitic, pisolitic, nodular, etc.). Terms which will be used ordinarily are oolitic (less than 2 mm.), pisolitic (2-8 mm.), nodular (more than 8 mm.), crystalline, and sandy. Instead of describing grain size by

Project:
Location of trench:

Formation: Member:
Bed no. Sample no.:
Fossil collection no:
Distance above base of formation:
Distance above base of member:
Thickness of bed: Of fossilif. zone:
Distance of zone above base of bed:
Lithology of bed:

Pct. of rock composed of fossils:
Recognizable phyla or classes and pct. of ea:

Recognizable genera, species, etc. and Pct. of ea:

Preservation:
    Type:
    Mineral composition:

    Condition:

Evidence of reworking:
Size of fossils and fragments:

Distribution within bed:

Orientation:

Special modes of occurrence:

Additional notes on ecology:

Miscellaneous notes:

Collectors: Date:

an adverb, give the common minimum and maximum, and median diameters, as: $\frac{1}{4}$-$1\frac{1}{2}$ mm.; 1 mm. This is best done in the field by comparison with a scale divided into hundredths of an inch--each division equals approximately $\frac{1}{4}$ mm.

Relative abundance of oolites, pisolites, etc., should be indicated by the adverbs slightly, moderately, and very (which will be taken to mean less than 20 percent, 20-50 percent, and more than 50 percent, respectively).

Oolites and pisolites have, by definition, concentric structure. Most of the so called oolites and pisolites of the phosphate rock do not have such structure, or at least do not display it prominantly. Strictly speaking, these grains should be designated by some other term, such as "ovules," but because identification of the internal structure is difficult in the field, and because the term "oolite" is well established for these grains, it seems best to continue using the term "oolite" in the field at least. Concentric structure, where observed, should be noted on the back of the page.

Sub-composition

Sub-composition, like sub-texture, includes such minerals or compounds as are present in an amount not warranting inclusion in the rock name. Examples of terms that may be used under this heading are micaceous, fluoritic, and ferruginous (generally indicated by red, brown, yellow, or green coatings).

Hardness

The properties determining hardness, toughness, cohersiveness, and crushing strength of rocks are difficult to define and, therefore, difficult to measure in the field. These properties, which are grouped here under the general term of "hardness" are of correlative value and of economic importance too, as they affect methods and costs of mining and processing. No quantitative method of evaluating hardness has been defined and until one is developed it is suggested that rocks that do not fracture or break with a single, sharp blow of a one-pound hammer be termed hard; those that break with such a blow but do not crumble, be termed medium hard or brittle (depending upon the nature of the fracture); and those that crumble or shatter or which show an imprint of the hammer head, be termed crumbly, soft, or plastic.

Color

The color of the rock should be determined by comparison with a color chart which will be provided. The color chart is based upon the Munsell system and is a modification of the chart being prepared by the Rock-color Chart Committee. In this system the colors are designated by numbers (as 5YR 8/1, meaning hue 5 yellow red, value, or lightness of 8 and chroma or saturation of 1; the number representing the value of the color increases from dark to light and that representing chroma increases from weak to strong or vivid) and groups or blocks of colors are designated by a single name. Most geologists, including myself, instinctively dislike referring to a color by number, but until suitable color names are devised for all colors, we will have to refer to the colors by number.

If the color of the rock is not uniform, notes on the variations in color should be made on the reverse of the chart. If the rock is wet at the time the color is described, a note should be made to that effect (e.g. 10YR 6/2, wet).

Thickness of bedding

Thickness of bedding, as used here, refers to the thickness of layers between visible cracks parallel to stratification. It may or may not be the same as the thickness of the unit or the thickness of individual layers described separately within each unit. The thickness of bedding should be given in feet and decimals of feet and both the range and average stated, as e.g., 0.1'-0.5'; 0.2'.

Size and shape of fragments

The description of the nature of jointing or fracturing of the rock on weathering should be stated under the heading "size and shape of fragments." The shape will be described by terms already in common usage, such as blocky, chippy, platy, chunky, flaggy, etc., and the size stated will be the intermediate diameter of the common largest fragments.

Reaction to HCl

The type of effervescence that develops on application of a drop of concentrated HCl to the rock should be noted as none, weak (bubbles form slowly and can be seen individually; effervescence does not break surface of drop), moderate (bubbles form rapidly, cannot be seen individually and break surface of drop but do not foam up), and strong (bubbles foam up and destroy shape of drop). The type of spot (faint white or yellow; white or yellow; and dense white or yellow) which develops on drying should be noted on the back of the page, as it is an indication of the amount of phosphate and iron present in the rock.

PREPARATION OF STRATIGRAPHIC SECTIONS

The stratigraphic sections of the Phosphoria formation measured and sampled in trenches or natural exposures, together with the analyses of the samples, represent our basic data. Regardless of how, or in what way, these data are ultimately interpreted it is evident that pains should be taken to make these sections of high quality--informative, accurate, grammatically acceptable and uniform in style and format. With this object in mind I have prepared the suggestions which follow and hope that those concerned will suggest any modifications or additions that seem appropriate.

Generally four types of stratigraphic sections will be prepared: 1) an abstract of the section containing only the unit numbers, sample numbers, thicknesses, rock names and fossil collection numbers; 2) a complete description of the section; 3) a columnar section graphically illustrating the rock types, the P_2O_5 and V_2O_5 contents and containing in tabular form an abbreviated description of each bed and the chemical analyses; 4) correlation charts showing relations between several stratigraphic columns.

Abstract of the section

The abstract of the section (pp. 21-24) will be prepared for the use of those who must handle the samples or keep track of the progress made in crushing, shipping, and analyzing the samples. It should be prepared immediately after the section is measured. The following should be included: 1) a heading, which should state the stratigraphic member described and the geographical name of the section as a title, followed by a paragraph repeating the title and giving the township, range, section, county, state and general geologic structure where the section was measured; peculiarities in section or samples thereof (e.g., state if section was pieced together from more than one trench) and nature of exposure (trench, natural outcrop, cross-cut, etc.); strike and dip of beds; names of geologists who measured and sampled the section and date (month and year) when samples were collected; 2) unit number, sample number, thickness, rock name, and fossil collection number (if any) of each unit in the member, to be listed in tabular form. The units should be listed from youngest (beginning at top of first page) to oldest. Twenty-five copies will be made of this section (by mimeograph).

Complete description of section

The principal use now envisioned for the complete written log of the section (pp. 25-34) will be its use as the first step in the preparation of the graphic column, though it may be put to other uses too. It should be prepared as soon as possible after the section is measured.

Heading

The heading will be the same as that given on the Abstract of the Section.

Bed description

The bed number, sample number, and thickness of each unit should be given in tabular form along the left-hand side of the page in columns appropriately headed. The rock description itself should be in sentence and paragraph form to the right.

Order of rock description

The elements composing each rock description should appear in the following order:

PHOSPHORIA FORMATION, COAL CANYON, WYOMING

Phosphoria formation sampled in Coal Canyon, T. 26 N., R. 119 W., Sec. 7, Lincoln County, Wyoming on east limb of Sublette anticline. Samples VEM-40-44 from vanadiferous zone in face of adit 50 feet above canyon bottom on north side; samples VEM-62-69-47 from natural exposure of Rex member 50 feet above canyon bottom on south side; samples VEM-70-96 from trench in upper shale member 200 feet above canyon bottom on south side; all others from trench in phosphatic shale member at bottom of canyon on the south side. Samples 2058-2087 collected in June, 1946; all others collected in June, 1947. Beds strike north and dip 75° east. Section measured by V. E. McKelvey, D. M. Larrabee, and L. E. Smith, and sampled by R. A. Gulbrandsen.

Abstract of the section

BED NO.	SAMPLE NO.	THICKNESS (FEET)	DESCRIPTION
Dinwoody formation:			
D-1	VEM-97-47	1.7	Limestone, argillaceous
Upper shale member of Phosphoria formation:			
U-21	VEM-96-47	1.7	Phosphate rock
U-20	VEM-95-47	0.6	Mudstone and chert
U-19	VEM-94-47	0.8	Limestone, cherty
U-18	VEM-93-47	4.0	Mudstone; limestone, and chert
U-17	VEM-92-47	1.6	Mudstone, cherty
U-16	VEM-91-47	1.6	Mudstone, cherty(?)
U-15	VEM-90-47	3.2	Like VEM-89-47
U-15	VEM-89-47	3.0	Mudstone
U-14	VEM-88-47	2.6	Like VEM-87-47
U-14	VEM-87-47	2.6	Mudstone, calcareous
U-13	VEM-86-47	1.6	Limestone, argillaceous
U-12	VEM-85-47	3.5	Like VEM-81-47
U-12	VEM-84-47	3.9	Ditto
U-12	VEM-83-47	3.7	Ditto
U-12	VEM-82-47	3.6	Ditto
U-12	VEM-81-47	4.3	Mudstone
U-11	VEM-80-47	1.4	Mudstone
U-10	VEM-79-47	1.0	Mudstone, calcareous
U-9	VEM-78-47	0.7	Mudstone
U-8	VEM-77-47	2.7	Mudstone
U-7	VEM-76-47	3.1	Mudstone
U-6	VEM-75-47	2.3	Chert
U-5	VEM-74-47	1.4	Mudstone, phosphatic(?)
U-4	VEM-73-47	0.6	Chert
U-3	VEM-72-47	1.1	Chert, phosphatic(?)
U-2	VEM-71-47	0.6	Chert, phosphatic(?)
U-1	VEM-70-47	0.4	Phosphate rock
		57.6	Total thickness of upper shale member.

BED NO.	SAMPLE NO.	THICKNESS (FEET)	DESCRIPTION
Rex member of Phosphoria formation:			
R-7	VEM-68-47	8.5	Like VEM-62-47; upper 1.4' resampled (VEM-63-47) in trench where upper shale was sampled.
R-6	VEM-67-47	9.0	Like VEM-62-47
R-5	VEM-66-47	10.5	Ditto
R-4	VEM-65-47	9.0	Ditto
R-3	VEM-64-47	10.4	Ditto, Fos. coll. No. 47 HW 48
R-2	VEM-63-47	9.8	Like VEM-62-47
R-1	VEM-62-47	9.6	Chert and limestone, Fos. coll. No. 47 HW 49
		66.8	Total thickness of Rex member.
Phosphatic shale member of Phosphoria formation:			
		13	Covered
P-106	DML-9-47	5.7	Limestone, dolomitic
P-105	DML-8-47	0.3	Phosphate rock
P-104	DML-7-47	0.4	Mudstone, micaceous
P-103	DML-6-47	0.5	Mudstone, micaceous
P-102	DML-5-47	0.5	Mudstone
P-101	DML-4-47	3.2	Mudstone
P-100	DML-3-47	1.2	Mudstone, micaceous
P-99	DML-2-47	0.4	Phosphate rock, argillaceous
P-98	DML-1-47	1.4	Mudstone, micaceous, slightly calcareous
			Upper phosphate zone
P-97	2063	1.1	Phosphate rock
P-96	2062	1.9	Phosphate rock
P-95	2061	0.7	Phosphate rock
P-94	2060	0.6	Phosphate rock
P-93	2059	0.5	Phosphate rock
P-92	2058	0.8	Phosphate rock
P-91	VEM-61-47	1.1	Phosphate rock
P-90	VEM-60-47	0.4	Mudstone, micaceous
P-89	VEM-59-47	1.9	Limestone
P-88	VEM-58-47	0.7	Phosphate rock
P-87	VEM-57-47	0.9	Phosphate rock, contains phosphatic(?), limestone lens 0.0-0.3' thick; not sampled.
P-86	VEM-56-47	0.6	Mudstone
P-85	VEM-55-47	0.5	Phosphate rock
P-84	VEM-54-47	0.9	Phosphate rock
P-83	VEM-53-47	1.8	Phosphate rock and phosphatic mudstone
P-82	VEM-52-47	1.0	Phosphate rock, limestone, and mudstone
P-81	VEM-51-47	1.7	Limestone
P-80	VEM-50-47	2.0	Mudstone and phosphate rock
P-79	VEM-49-47	1.0	Phosphate rock and limestone
P-78	VEM-48-47	0.8	Mudstone, phosphatic
P-77	VEM-47-47	0.4	Phosphate rock
P-76	VEM-46-47	2.1	Mudstone and phosphate rock
P-75	VEM-45-47	1.6	Hanging-wall limestone

Upper shale member of Phosphoria formation. (cont'd.):

BED NO.	SAMPLE NO.	THICKNESS (FEET)	DESCRIPTION
			Vanadiferous zone
P-74	VEM-44-47	0.2	Mudstone
P-73	VEM-44-47	0.55	Ditto
P-72	VEM-43-47	0.4	Ditto
P-71	VEM-42-47	0.65	Ditto
P-70	VEM-41-47	0.9	Ditto
P-69	VEM-40-47	1.05	Ditto
P-68	VEM-39-47	1.1	Footwall limestone
P-67	VEM-38-47	1.5	Mudstone, micaceous
P-66	VEM-37-47	1.4	Mudstone
P-65	VEM-36-47	0.5	Ditto
P-64	VEM-35-47	2.3	Limestone, argillaceous
P-63	VEM-34-47	3.0	Mudstone and limestone
P-62	VEM-33-47	0.7	Mudstone, calcareous
P-61	VEM-32-47	2.0	Mudstone, phosphatic(?)
P-61	VEM-31-47	2.0	Like VEM-32-47
P-60	VEM-30-47	3.5	Limestone, argillaceous
P-59	VEM-29-47	1.1	Mudstone, calcareous
P-58	VEM-28-47	3.0	Mudstone, 0.0-0.2', limestone lens--included in sample
P-57	VEM-27-47	1.6	Mudstone, phosphatic, calcareous
P-56	VEM-26-47	1.6	Mudstone, phosphatic
P-55	VEM-25-47	1.2	Mudstone, calcareous
P-54	VEM-24-47	1.6	Mudstone, phosphatic
P-53	VEM-23-47	1.3	Mudstone, calcareous
P-52	VEM-22-47	2.5	Mudstone and phosphate rock
P-51	VEM-21-47	0.7	Mudstone, calcareous
P-50	VEM-20-47	0.3	Phosphate rock
P-49	VEM-19-47	1.3	Mudstone. Fault (strikes N. 10° W. dips 60° E.) truncates beds 49 and 50
P-48	VEM-18-47	0.6	Phosphate rock
P-47	VEM-17-47	1.1	Mudstone, slightly calcareous
P-46	VEM-16-47	1.1	Mudstone, calcareous
P-45	VEM-15-47	1.1	Mudstone
P-44	VEM-14-47	0.8	Phosphate rock
P-43	LES-10-47	1.3	Ditto
P-42	LES-9-47	0.7	Ditto
P-41	LES-8-47	2.0	Mudstone
P-40	LES-7-47	3.8	Mudstone, slightly calcareous
P-39	LES-6-47	3.0	Ditto
P-38	LES-5-47	0.6	Mudstone
P-37	LES-4-47	1.8	Ditto
P-36	LES-3-47	0.6	Mudstone, calcareous
P-35	LES-2-47	0.9	Ditto
P-34	LES-1-47	0.4	Mudstone, phosphatic
P-33	VEM-13-47	0.6	Phosphate rock
P-32	2086	0.8	Mudstone and phosphate rock
P-31	2085	0.4	Mudstone, phosphatic
P-30	2085	1.4	Mudstone, calcareous

BED NO.	SAMPLE NO.	THICKNESS (FEET)	DESCRIPTION
Upper shale member of Phosphoria formation, (cont'd.):			
P-29	2084	1.0	Mudstone, phosphatic
P-28	2083	0.9	Mudstone, phosphatic
P-27	2082	0.8	Ditto
P-26	2081	1.7	Mudstone, calcareous, phosphatic
P-25	2080	1.2	Phosphate rock
P-24	2079	2.1	Phosphate rock, 0.0-0.25', dolomite lens 1.4' above base
P-23	2078	0.3	Phosphate rock
P-22	2077	1.7	Like 2076
P-22	2076	1.7	Phosphate rock
P-21	2075	0.8	Like 2074
P-21	2074	0.9	Mudstone, phosphatic
P-20	2073	1.2	Ditto
P-19	2072	1.1	Ditto
P-18	2071	0.7	Limestone, argillaceous, phosphatic
P-17	2070	0.4	Mudstone, slightly calcareous, phosphatic
P-16	2069	2.3	Limestone, argillaceous
P-15	VEM-12-47	1.3	Mudstone, phosphatic(?), calcareous
P-14	VEM-11-47	0.5	Mudstone, phosphatic, calcareous
P-13	VEM-10-47	0.9	Ditto
P-12	VEM-9-47	0.5	Ditto
P-11	VEM-8-47	0.7	Phosphate rock
P-10	VEM-7-47	0.4	Mudstone, phosphatic
P-9	2066	1.4	Mudstone, calcareous, phosphatic
P-8	2065	0.4	Phosphate rock
P-7	2064	0.5	Mudstone, micaceous
P-6	VEM-6-47	2.6	Mudstone, calcareous, micaceous
P-5	VEM-5-47	0.5	Mudstone, micaceous
P-4	VEM-4-47	0.6	Ditto
P-3	VEM-3-47	0.5	Mudstone
P-2	VEM-2-47	1.4	Ditto
P-1	VEM-1-47	0.2	Phosphate rock
		143.75	Total thickness of Phosphatic shale member
Wells formation:			
W-1	Not sampled	4.3	Limestone, finely sandy
W-2	Ditto	2.8	Limestone
W-3	Ditto	3.0	Siltstone, finely sandy, calcareous
W-4	Ditto	3.8	Limestone, sandy
W-5	Ditto	9.0+	Limestone
	Approximately 50		

PHOSPHORIA FORMATION, COAL CANYON, WYOMING

Phosphoria formation sampled in Coal Canyon, T. 26 N., R. 119 W., Sec. 7, Lincoln County, Wyoming, on east limb of Sublette anticline. Samples VEM-40-44 from vanadiferous zone in face of adit 50 feet above canyon bottom on north side; samples VEM-62-69-47 from natural exposure of Rex member 50 feet above canyon bottom on south side; samples VEM-70-96 from trench in upper shale member 200 feet above canyon bottom on south side; all others from trench in phosphatic shale member at bottom of canyon on the south side. Samples 2058-2087 collected in June, 1946; all others collected in June, 1947. Beds strike north and dip 75° east. Section measured by V. E. McKelvey, D. M. Larrabee, and L. E. Smith, and sampled by R. A. Gulbrandsen.

Complete description of section

BED NO.	SAMPLE NO.	THICKNESS (FEET)	DESCRIPTION
Dinwoody formation:			
D-1	VEM-97-47	1.7	Limestone: argillaceous, hard, light yellowish-gray and brownish-gray, thin-bedded; grades from phosphate rock below; lower 0.2' contains phosphatic pisolites.
Upper shale member of Phosphoria formation:			
U-21	VEM-96-47	1.7	Phosphate rock: coarsely pisolitic, medium hard, grayish-brown, massive; soft and yellow-brown stained in upper 0.4'.
U-20	VEM-95-47	0.6	Mudstone and chert: 0.3' moderately calcareous, weak brown, fissile mudstone interbedded with 0.3' brittle black, thin-bedded chert.
U-19	VEM-94-47	0.8	Limestone: cherty, hard, black, thin-bedded.
U-18	VEM-93-47	4.0	Mudstone, limestone, chert: 2.9' cherty, hard, grayish-brown mudstone, grading from cherty mudstone below; 0.8' hard, grayish-brown limestone; 0.3' brittle black chert at top.
U-17	VEM-92-47	1.6	Mudstone: cherty, brittle, black (dark-brown and yellowish-brown weathered) thick-bedded; grades from mudstone below.
U-16	VEM-91--47	1.6	Mudstone: cherty(?), hard, brownish-black (moderate and dark-yellowish-brown weathered), thin-bedded; grades from mudstone below; nodules in upper 0.2'. Fos. coll. No. 47 EW 47.
U-15	VEM-90-47	3.2	Like VEM-89-47 and part of same bed.
U-15	VEM-89-47	3.0	Mudstone: soft and medium hard, brownish-black, thin-bedded, ellipsoidally weathered (ellipses 0.05' x 0.1' x 0.3').
U-14	VEM-88-47	2.6	Like VEM-87 and part of same bed; contains 0.03' chert at top.
U-14	VEM-87-47	2.6	Mudstone: calcareous, hard, brownish-black, thin-bedded; soft and non-calcareous (leached) in upper part.
U-13	VEM-86-47	1.6	Limestone: argillaceous, hard, black, massive.
U-12	VEM-85-47	3.5	Like VEM-81-47 and part of same bed.

BED NO.	SAMPLE NO.	THICKNESS (FEET)	DESCRIPTION
Upper shale member of Phosphoria formation, (cont'd.):			
U-12	VEM-84-47	3.9	Like VEM-81-47 and part of same bed.
U-12	VEM-83-47	3.7	Ditto.
U-12	VEM-82-47	3.6	Ditto.
U-12	VEM-81-47	4.3	Mudstone: hard, grayish-brown, thick-bedded; grades from mudstone below.
U-11	VEM-80-47	1.4	Mudstone: slightly calcareous, medium hard, brownish black, thin-bedded.
U-10	VEM-79-47	1.0	Mudstone: calcareous, hard, brownish-gray; thin-bedded, more calcareous in upper half.
U-9	VEM-78-47	0.7	Mudstone: soft, dusky-brown, fissile.
U-8	VEM-77-47	2.7	Mudstone: soft to medium hard, brownish-black, thin-bedded; grades from mudstone below.
U-7	VEM-76-47	3.1	Mudstone: medium hard, brownish-black, thick-bedded; slightly calcareous in upper 2.0'.
U-6	VEM-75-47	2.3	Chert: brittle, black, thin-bedded; lower contact irregular: 0.2' brecciated bed 1.0' above base; upper 0.5' more massive and hard.
U-5	VEM-74-47	1.4	Mudstone: very finely oolitic, phosphatic(?), cherty hard, dark-yellowish-brown and dark-gray, moderate yellowish-brown along joints, thin-bedded in lower 0.4', thick-bedded in upper 1.0'; lower contact irregular.
U-4	VEM-73-47	0.6	Chert: hard, black; thin-bedded.
U-3	VEM-72-47	1.1	Chert: phosphatic(?), hard, black, thick-bedded; quartzitic appearance.
U-2	VEM-71-47	0.6	Chert: finely oolitic, phosphatic(?), hard, brownish-black, thick-bedded.
U-1	VEM-70-47	0.4	Phosphate rock: finely oolitic, soft, dusky-brown, thin-bedded; lower contact irregular.
		57.6	Total thickness of upper shale member.
Rex member of Phosphoria formation:			
R-7	VEM-68-47	8.5	Like VEM-62-47: upper 1.4' resampled (VEM-63-47) in trench where upper shale was sampled.
R-6	VEM-67-47	9.0	Like VEM-62-47
R-5	VEM-66-47	10.5	Ditto.
R-4	VEM-65-47	9.0	Ditto.
R-3	VEM-64-47	10.4	Ditto. Fos. coll. No. 47 HW 48.
R-2	VEM-63-47	9.8	Like VEM-62-47.
R-1	VEM-62-47	9.6	Chert and limestone: hard, black, massive chert interbedded with layers of hard, brownish gray massive layers of limestone up to about 1.0' thick, which composes only about 10 percent of section. Fos. coll. No. 47 HW 49.
		66.8	Total thickness of Rex member.

BED NO.	SAMPLE NO.	THICKNESS (FEET)	DESCRIPTION
Phosphatic shale member of Phosphoria formation:			
		13	Covered.
P-106	DML-9-47	5.7	Limestone: dolomitic, hard, black, massive.
P-105	DML-8-47	0.3	Phosphate rock: finely oolitic, soft, black, thin-bedded.
P-104	DML-7-47	0.4	Mudstone: micaceous, soft, brownish-black, thin-bedded; grades from mudstone below. Fos. coll. No. 47 HW 46.
P-103	DML-6-47	0.5	Mudstone: micaceous, soft, brownish-black, thin-bedded; grades from mudstone below; lower 0.2' oolitic and slightly calcareous.
P-102	DML-5-47	0.5	Mudstone: slightly micaceous, soft, brownish-black, thin-bedded; grades from mudstone below; slightly calcareous at top.
P-101	DML-4-47	3.2	Mudstone: slightly micaceous, soft, brownish-black, fissile; grades from mudstone below; slightly calcareous in upper part.
P-100	DML-3-47	1.2	Mudstone: micaceous, medium hard, brownish-black, thin-bedded; grades from phosphate rock below.
P-99	DML-2-47	0.4	Phosphate rock: finely oolitic, argillaceous, soft, black, fissile; grades from mudstone below; micaceous, more coarsely oolitic, and slightly calcareous in upper part. Fos. coll. No. 47 HW 45.
P-98	DML-1-47	1.4	Mudstone: micaceous, slightly calcareous, hard, brownish-gray, thick-bedded. Fos. coll. No. 47 HW 44.
			Upper phosphate zone
P-97	2063	1.1	Phosphate rock: coarsely oolitic, micaceous, hard, dark-gray, thin-bedded; upper 0.3' brownish-black and argillaceous.
P-96	2062	1.9	Phosphate rock: coarsely oolitic, hard, black, thick-bedded.
P-95	2061	0.7	Phosphate rock: finely oolitic, slightly micaceous, medium hard, dark-gray, thin-bedded.
P-94	2060	0.6	Phosphate rock: finely oolitic, medium hard, dark-gray to black, thin-bedded.
P-93	2059	0.5	Phosphate rock: finely oolitic, slightly micaceous, medium hard, dark-gray to black, thin-bedded.
P-92	2058	0.8	Phosphate rock: finely oolitic, medium hard, dark-gray, thin-bedded; grades from phosphate rock below.
P-91	VEM-61-47	1.1	Phosphate rock: finely oolitic, micaceous, soft, brownish-black, thin-bedded; grades from mudstone below; more coarsely oolitic upward.
P-90	VEM-60-47	0.4	Mudstone: micaceous, soft, brownish-black, massive.
P-89	VEM-59-47	1.9	Limestone: hard, grayish-brown, massive; upper 0.2' argillaceous, less calcareous, brownish black.

BED NO.	SAMPLE NO.	THICKNESS (FEET)	DESCRIPTION
Phosphatic shale member of Phosphoria formation, (cont'd.):			
P-88	VEM-58-47	0.7	Phosphate rock: finely oolitic, medium hard, brownish-black, thin-bedded.
P-87	VEM-57-47	0.9	Phosphate rock: coarsely and medium coarsely oolitic, medium hard, black, thin-bedded. Contains phosphatic(?), medium coarsely oolitic, hard, dark-gray limestone lens 0.0-0.3' thick: not sampled.
P-86	VEM-56-47	0.6	Mudstone: slightly calcareous, soft; brownish-black, thin-bedded. Contains a few 0.01' layers of finely oolitic phosphate rock.
P-85	VEM-55-47	0.5	Phosphate rock: medium coarsely oolitic, soft, brownish-black, thin-bedded.
P-84	VEM-54-47	0.9	Phosphate rock: medium coarsely to very coarsely oolitic, medium hard, dark-gray and black, thick-bedded.
P-83	VEM-53-47	1.8	Phosphate rock and phosphatic mudstone: 0.4' finely oolitic, soft, black, thin-bedded phosphate rock; overlain by 0.5' very finely oolitic, phosphatic, medium hard, brownish-black, thin-bedded mudstone; overlain by 0.9' finely oolitic, phosphatic, medium hard, black, thin-bedded mudstone.
P-82	VEM-52-47	1.0	Phosphate rock, limestone, and mudstone: 0.5' very coarsely oolitic, crumbly, calcareous(?), black (some oolites light gray), thick-bedded fossiliferous phosphate rock; overlain by 0.3' medium coarsely oolitic, crumbly, black, thick-bedded phosphate rock; overlain by 0.1' soft, brownish-black, thin-bedded mudstone; overlain by 0.1' hard, grayish-brown, thin-bedded limestone.
P-81	VEM-51-47	1.7	Limestone: hard, dark-gray, massive. Dusky-yellow coatings on joints. Fos. coll. No. 47 HW 43.
P-80	VEM-50-47	2.0	Mudstone and phosphate rock: 0.4' micaceous, soft; brownish-black, fissile mudstone; overlain by 1.35' slightly calcareous, medium hard, brownish-black, thin-bedded mudstone; overlain by 0.25' finely to coarsely oolitic, crumbly, black, thick-bedded phosphate rock.
P-79	VEM-49-47	1.0	Phosphate rock and limestone (listed from oldest to youngest): o.1' finely to coarsely oolitic, crumbly, black (wet), thin-bedded phosphate rock; 0.1' finely to coarsely oolitic, calcareous, crumbly, black, thin-bedded phosphate rock; 0.1' finely to coarsely oolitic, crumbly, black, thin-bedded phosphate rock; 0.2' micaceous, soft, brownish-black, fissile mudstone; 0.1' argillaceous, hard, dark-gray (dusky-yellow weathered), limestone; 0.1' finely to coarsely oolitic, crumbly, black phosphate rock; 0.1' argillaceous, hard, dark-gray limestone; finely to coarsely oolitic, crumbly, black phosphate rock.

BED NO.	SAMPLE NO.	THICKNESS (FEET)	DESCRIPTION
Phosphatic shale member of Phosphoria formation, (cont'd.):			
P-78	VEM-48-47	0.8	Mudstone: lower 0.6', finely oolitic, phosphatic, medium hard, brownish-black (wet), thin-bedded; grades from mudstone below; upper 0.2' soft, more thin-bedded.
P-77	VEM-47-47	0.4	Phosphate rock: medium coarsely oolitic, crumbly, black, thin-bedded.
P-76	VEM-46-47	2.1	Mudstone and phosphate rock: (listed from oldest to youngest), 0.5' soft, black, fissile mudstone; 0.1' finely oolitic, phosphatic, black, fissile mudstone; 0.3' calcareous, hard, grayish-brown, thick-bedded mudstone; 0.3' soft, black, fissile mudstone; 0.3' calcareous hard, grayish-brown, thick-bedded mudstone; 0.05' finely oolitic, phosphatic, soft, black fissile mudstone; 0.1' calcareous, hard, grayish-brown, thin-bedded mudstone; 0.05' finely oolitic; soft, black, fissile phosphate rock; 0.05' calcareous, hard, grayish-brown, thin-bedded mudstone; 0.05' finely oolitic soft, black, fissile phosphate rock; 0.3' calcareous, hard, grayish-brown, thick-bedded mudstone.
P-75	VEM-45-47	1.6	Hanging-wall limestone: hard, brownish-gray, massive. Fos. coll. No. 47 HW 42.
			Vanadiferous zone
P-74	VEM-44-47	0.2	Mudstone: hard, black, thick-bedded. Contains five 0.01' laminae of finely oolitic phosphate rock in lower 0.1'.
P-73	VEM-44-47	0.55	Mudstone: hard, black, thick-bedded. Contains phosphatic elliptical nodules up to 0.1' in diameter on lower surface.
P-72	VEM-43-47	0.4	Mudstone: hard, black, thin-bedded. 0.02' calcite vein along lower contact.
P-71	VEM-42-47	0.65	Mudstone: hard, black, thick-bedded.
P-70	VEM-41-47	0.9	Mudstone: hard, black, thick-bedded.
P-69	VEM-40-47	1.05	Mudstone: hard, black, thick-bedded but composed of alternating 0.005' to 0.01' laminae of calcareous mudstone and finely oolitic, phosphatic (?), calcareous, mudstone.
P-68	VEM-39-47	1.1	Footwall limestone: hard, brownish-gray (wet), thick-bedded, fossiliferous. Fos. coll. No. 47 HW 35.
P-67	VEM-38-47	1.5	Mudstone: micaceous, soft, black (wet), fissile; grades from mudstone below. Strong-yellow coating on lower 0.2'.
P-66	VEM-37-47	1.4	Mudstone: medium hard, brownish-black (wet), massive upper 0.4' soft, thin-bedded. Yellowish-white and very pale-brown coatings on joint surfaces.
P-65	VEM-36-47	0.5	Mudstone: soft, brownish-black (wet) thin-bedded; upper 0.1' very finely oolitic. Dusky-reddish brown and moderate-yellow coatings on joint surfaces.

BED NO.	SAMPLE NO.	THICKNESS (FEET)	DESCRIPTION
Phosphatic shale member of Phosphoria formation (cont'd.):			
P-64	VEM-35-47	2.3	Limestone: argillaceous, granular, hard, brownish-black (wet), massive in lower 1.4', thick-bedded in upper 0.9'; upper 0.25' more argillaceous and medium hard. Yellowish-white coatings on joints.
P-63	VEM-34-47	3.0	Mudstone and limestone: eight, soft, black (wet), fissile mudstone layers 0.2' to 0.7' thick interbedded with seven argillaceous, brownish-black (wet), thin-bedded, limestone layers 0.05-0.15' thick. Some mudstone layers are locally finely oolitic.
P-62	VEM-33-47	0.7	Mudstone: calcareous, granular appearance, medium hard, brownish-black (wet), thick-bedded. Yellowish-white coating on joint surfaces.
P-61	VEM-32-47	2.0	Mudstone: finely oolitic, phosphatic(?), soft black (wet) fissile mudstone interbedded with calcareous, hard, brownish-black (wet) thin-bedded mudstone. Contains hard, brownish-gray, massive limestone lens 0.0' to 0.8' thick, 1.4' below top--not sampled. Lower, contact irregular.
P-61	VEM-31-47	2.0	Like VEM-32-47: grades from limestone below.
P-60	VEM-30-47	3.5	Limestone: argillaceous, hard, brownish gray (wet), thick-bedded and massive; black, less calcareous, medium hard in upper 0.4'; pale yellow coatings. Thickness varies from 2.6' to 3.5' (may be a lens). Fos. coll. No. 1-9/9/47(JSW).
P-59	VEM-29-47	1.1	Mudstone: calcareous, medium hard, black (wet), thick-bedded. Pale-yellow, yellowish-white and very pale-brown coatings on joints.
P-58	VEM-28-47	3.0	Mudstone: (listed from oldest to youngest); 0.7' very finely oolitic, phosphatic(?), micaceous, soft, brownish-black (wet) fissile mudstone; grades from mudstone below; 0.8' very finely oolitic, phosphatic, soft, black (wet), fissile, mudstone; 0.0'-0.2' hard, brownish-black (yellowish-white coatings on joint surfaces), limestone lens--included in sample; 0.5' very finely oolitic, phosphatic, soft, black, fissile mudstone; 0.2' calcareous, soft black, thin-bedded mudstone; 0.6' very finely oolitic, phosphatic, soft, black mudstone.
P-57	VEM-27-47	1.6	Mudstone: very finely oolitic, phosphatic, calcareous soft, black (wet), thin-bedded; lower contact wavy--thickness varies from 1.6' to 2.2' (may be in lens). Yellowish-white coating on joint surfaces.
P-56	VEM-26-47	1.6	Mudstone: very finely oolitic, phosphatic, soft, black, fissile.
P-55	VEM-25-47	1.2	Mudstone: calcareous, medium hard, brownish black (wet), thick-bedded; very finely oolitic in upper 0.2'. Yellowish-white coating on joint surfaces.

BED NO.	SAMPLE NO.	THICKNESS (FEET)	DESCRIPTION
Phosphatic shale member of Phosphoria formation (cont'd.):			
P-54	VEM-24-47	1.6	Mudstone: very finely oolitic, phosphatic, soft, black (wet), thin-bedded; grades from calcareous mudstone below.
P-53	VEM-23-47	1.3	Mudstone: calcareous, medium hard, brownish black (wet), thin-bedded; upper 0.2' more thin-bedded, soft. Yellowish white coatings on joint surfaces.
P-52	VEM-22-47	2.5	Mudstone and phosphate rock: about forty 0.01-0.2' layers of alternating medium coarsely oolitic, crumbly, black (wet), thin-bedded phosphate rock and medium coarsely oolitic, phosphatic, soft, black mudstone; lower 0.1' finely and coarsely pisolitic.
P-51	VEM-21-47	0.7	Mudstone: calcareous, hard, brownish-black (wet), thick-bedded. Yellowish-white coatings on joint surfaces. 0.2' layer very coarsely oolitic phosphate rock 0.15' below top.
P-50	VEM-20-47	0.3	Phosphate rock: coarsely oolitic, crumbly, black (wet), thin-bedded. Upper 0.1' nodular.
P-49	VEM-19-47	1.3	Mudstone: soft, brownish-black (wet), thin-bedded; yellowish-white coatings on joint surfaces; lower 0.3' slightly phosphatic, finely oolitic; upper 0.4' slightly calcareous. Fault (strikes N.10° W. dips 60° E) truncates beds 49 and 50.
P-48	VEM-18-47	0.6	Phosphate rock: finely to very coarsely oolitic, crumbly, black, thin-bedded.
P-47	VEM-17-47	1.1	Mudstone: slightly calcareous, soft, black (soft), fissile.
P-46	VEM-16-47	1.1	Mudstone: calcareous, soft, brownish-black (wet), thick-bedded; yellowish-white coating on joint surfaces; upper 0.7' medium hard, more calcareous. Thickness varies from 1.1' to 1.3'. Bed forms the part of the roof and east wall of old coal (?) prospect adit.
P-45	VEM-15-47	1.1	Mudstone: soft, black (wet), fissile and thin-bedded; weak yellow coatings on joint surfaces.
P-44	VEM-14-47	0.8	Phosphate rock: finely to coarsely oolitic, crumbly, black, thin-bedded; grades from phosphate rock below.
P-43	LES-10-47	1.3	Phosphate rock: medium coarsely oolitic, crumbly black, lower 0.45' and upper 0.25' finely oolitic and brittle; grades from phosphate rock below.
P-42	LES-9-47	0.7	Phosphate rock: medium-coarsely, lower half brittle, upper half crumbly, oolitic, black; grades from mudstone below. Forms west wall of adit.
P-41	LES-8-47	2.0	Mudstone: medium hard, brownish-grey, massive; upper 0.15' medium-coarsely oolitic.
P-40	LES-7-47	3.8	Mudstone: slightly calcareous, medium hard, brownish-black; arbitrarily separated from LES-6-47.
P-39	LES-6-47	3.0	Mudstone: slightly calcareous, medium hard, brownish-black, thin-bedded; grades from mudstone below. Yellowish-white coatings on joints.

BED NO.	SAMPLE NO.	THICKNESS (FEET)	DESCRIPTION
Phosphatic shale member of Phosphoria formation (cont'd.):			
P-38	LES-5-47	0.6	Mudstone: medium hard, brownish-black, thick-bedded in lower 0.4', thin-bedded in upper 0.2'; thickness varies from 0.6' to 0.7'.
P-37	LES-4-47	1.8	Mudstone: medium hard, brownish-black, thin-bedded (thinner bedded in upper part); grades from mudstone below. Yellowish-white coatings on joint surfaces--abundant in lower half.
P-36	LES-3-47	0.6	Mudstone: moderately calcareous, micaceous, medium hard, brownish-black, thick-bedded. Yellowish white coating on joint surfaces.
P-35	LES-2-47	0.9	Mudstone: moderately calcareous, micaceous, medium hard, brownish black,--thin-bedded in lower and upper parts, thick-bedded, more strongly calcareous, hard in middle. Yellowish-white coatings on joint surfaces.
P-34	LES-1-47	0.4	Mudstone: very finely oolitic, phosphatic, medium hard, black, thin-bedded. Yellowish-white coatings on joints.
P-33	VEM-13-47	0.6	Phosphate rock: very finely oolitic, soft, black (wet), thin-bedded in lower part, thick-bedded in upper part.
P-32	2086	0.8	Mudstone and phosphate rock: lower 0.55' soft, black, thin-bedded, mudstone, containing weak reddish-brown coatings on joint surfaces; upper 0.3' finely oolitic, soft, black phosphate rock.
P-31	2085	0.4	Mudstone: very finely oolitic, phosphatic, soft, black (wet), thin-bedded; fissile in upper 0.15'.
P-30	2085	1.4	Mudstone: calcareous, medium hard, brownish-black (wet); non-calcareous in lower 0.3'; dusky-brown in upper 0.5'. Yellowish-white coatings on joint surfaces in lower 0.9'; especially prominent in lower 0.1'.
P-29	2084	1.0	Mudstone: phosphatic, soft, black (wet); thin-bedded; fissile in middle 0.1'.
P-28	2083	0.9	Mudstone: phosphatic, micaceous, soft, black (wet), thin-bedded, fissile in upper 0.3'.
P-27	2082	0.8	Mudstone: phosphatic, soft, black (wet), thin-bedded; grades from calcareous mudstone below.
P-26	2081	1.7	Mudstone: calcareous, phosphatic, medium hard, brownish-black, thick-bedded; thin-bedded and less calcareous in upper and lower 0.2'; grades from phosphate rock below.
P-25	2080	1.2	Phosphate rock: very finely oolitic, soft, black (wet), thin-bedded. Grades from phosphate rock below.
P-24	2079	2.1	Phosphate rock: very finely oolitic, soft, brownish-black (wet), thin-bedded; yellowish-gray coatings along joints. 0.0-0.25' hard, brownish-gray dolomite lens 1.4' above base.
P-23	2078	0.3	Phosphate rock: very finely oolitic, soft, black (wet), thin-bedded.

BED NO.	SAMPLE NO.	THICKNESS (FEET)	DESCRIPTION
Phosphatic shale member of Phosphoria formation (cont'd.):			
P-22	2077	1.7	Like 2076.
P-22	2076	1.7	Phosphate rock: very finely oolitic, soft, black (wet), thin-bedded; grades from mudstone below. Yellowish-gray coatings on joint surfaces.
P-21	2075	0.8	Like 2074.
P-21	2074	0.9	Mudstone: finely oolitic, phosphatic, soft, black, thin-bedded. Yellowish-gray on joint surfaces.
P-20	2073	1.2	Mudstone: phosphatic, slightly calcareous, medium hard, brownish-black, Light yellowish-gray coatings on joint surfaces.
P-19	2072	1.1	Mudstone: very finely oolitic, phosphatic, soft, black (wet), thin-bedded; grades from limestone below.
P-18	2071	0.7	Limestone: argillaceous, phosphatic, medium hard, brownish-black, thick-bedded. Upper 0.2' less calcareous. Light yellowish-gray coatings on joint surfaces.
P-17	2070	0.4	Mudstone: slightly calcareous, phosphatic, soft, black (wet), thin-bedded; lower 0.15' very finely oolitic and moderately calcareous; upper 0.02' calcareous, plastic, light yellowish-brown clay.
P-16	2069	2.3	Limestone: argillaceous, hard, brownish-black (wet), thick-bedded; 0.1' layers of medium coarsely oolitic, black phosphate rock 1.0' and 1.6' above base. Lower contact slightly discordant.
P-15	VEM-12-47	1.3	Mudstone: phosphatic(?), calcareous, soft, black (wet), thin-bedded.
P-14	VEM-11-47	0.5	Mudstone: finely oolitic, phosphatic, calcareous, hard, brownish-gray, thick-bedded. Grades from mudstone below.
P-13	VEM-10-47	0.9	Mudstone: finely oolitic, phosphatic, calcareous, medium hard, brownish-black (wet), massive; grades from mudstone below. Less oolitic in upper part.
P-12	VEM-9-47	0.5	Mudstone: finely to coarsely oolitic, phosphatic, calcareous, medium hard, brownish-black (wet), thick-bedded; grades from phosphate rock below. Light yellowish-gray coatings on joint surfaces.
P-11	VEM-8-47	0.7	Phosphate rock: finely oolitic, medium hard, black (wet), thin-bedded.
P-10	VEM-7-47	0.4	Mudstone: finely oolitic, phosphatic, soft, black (wet), fissile.
P-9	2066	1.4	Mudstone: calcareous, phosphatic, medium hard, black (brownish-gray weathered), thin-bedded.
P-8	2065	0.4	Phosphate rock: finely oolitic, soft, black, thin-bedded.
P-7	2064	0.5	Mudstone: micaceous, soft, black, thin-bedded; strong-brown coatings on joint surfaces; grades from mudstone below.

BED NO.	SAMPLE NO.	THICKNESS (FEET)	DESCRIPTION
Phosphatic shale member of Phosphoria formation (cont'd.):			
P-6	VEM-6-47	2.6	Mudstone: calcareous, micaceous, hard, brownish-black, thick-bedded; medium hard, moderately calcareous in upper 0.35'. Very pale-brown coatings on joints. Grades from mudstone below.
P-5	VEM-5-47	0.5	Mudstone: micaceous, medium hard, brownish-black, thick-bedded; grades from mudstone below. Yellowish-white coatings on joint surfaces.
P-4	VEM-4-47	0.6	Mudstone: micaceous, soft, black, thin-bedded; grades from mudstone below. Dark reddish-brown coatings on joint surfaces in upper half; reddish-brown and light olive coatings below.
P-3	VEM-3-47	0.5	Mudstone: medium hard, black, thin-bedded; grades from mudstone below. Dark reddish-brown and moderate yellow coatings on joint surfaces.
P-2	VEM-2-47	1.4	Mudstone; slightly micaceous, medium hard, brownish-black, thin-bedded. Light yellowish-gray on joint surfaces.
P-1	VEM-1-47	0.2	Phosphate rocks: coarsely oolitic, hard, black (pale brown weathered), thick-bedded. No bedding plane (i.e. crack) between this bed and Wells formation below.
		143.75	Total thickness of Phosphatic shale member.
Wells formation:			
W-1	Not sampled	4.3	Limestone: finely crystalline, finely sandy, hard, medium-gray (very pale-brown weathered), thick-bedded.
W-2	Ditto	2.8	Limestone: finely crystalline, hard, light brownish-gray and brownish-gray, thick-bedded.
W-3	Ditto	3.0	Siltstone: finely sandy, calcareous, soft, pale brown, thin-bedded.
W-4	Ditto	3.8	Limestone: sandy, hard in lower half, soft in upper half, light-gray, thick-bedded.
W-5	Ditto	9.0+	Limestone: hard, brownish-gray (light gray weathered), thick-bedded. Interval, largely covered to top of unit formerly mapped as Weber quartzite.
	Approximately 50		

1) Rock name (noun only)

2) Adjectives describing composition (phosphatic, calcareous, micaceous, argillaceous, cherty, etc.)

3) Adjective and/or adverb describing size of oolities, pisolites or nodules (on the Coal Canyon section, pp. 25-34, this precedes instead of follows the adjective describing composition; the usage given here is the one we will follow in the future.)

    >8 mm. -- nodular
    4 - 8 mm. -- coarsely pisolistic
    2 - 4 mm. -- finely pisolistic
    1 - 2 mm. -- very coarsely oolitic
    1/2 - 1 mm. -- coarsely oolitic
    1/4 - 1/2 mm. -- medium coarsely oolitic
    1/8 - 1/4 mm. -- finely oolitic
    $<1/8$ mm. -- very finely oolitic

4) Adjectives and/or adverbs describing crystalline or clastic texture. Sandy texture may be defined by the same terms used to define oolitic texture as given above (the adverbs adapted conform to the Wentworth scale); crystalline textures may be described as follows:

    >4 mm. -- coarsely crystalline
    1 - 4 mm. -- medium crystalline
    <1 mm. -- finely crystalline
    grains too small to distinguish separately -- dense

5) Hardness (use only terms crumbly, plastic, semi-plastic, soft, medium hard, brittle, and hard)

6) Color

7) Thickness of bedding:

    $>1.0'$ -- massive
    0.2 - 1.0' -- thick bedded
    0.02 - 0.2' -- thin bedded
    $<0.02'$ -- fissile

8) Fossils

9) Irregularities in lower contact

10) Internal gradations

11) Lenses or concretions

12) Maximum size of fragments

13) Additional remarks

If more than one rock type is present in unit, give names of all or of principal rocks first, then describe each (from oldest to youngest), giving first the thickness (not distance above base), adjectives in the order listed above, and the noun last. Indicate doubt in accuracy of any portion of description by a parenthetical query (?), followed by another punctuation mark.

Punctuation

The rock name should be followed by a colon, each adjective followed by a comma, and the whole statement closed by a period. Additional remarks can be stated as separate sentences. If more than one rock type is described, close the description of each with a semi-colon. Words combined to form a unit modifier are hyphened unless the first word is an adverb ending in ly or the first word of a three-word modifier is an adverb and modifies the second (e.g. thin-bedded mudstone; very pale-brown limestone).

General advice on composition and style

The rock description should be grammatically correct even though it will necessarily be telegraphic. A description containing no plot is better than one having a mystery introduced through confusion of antecedents, careless punctuation or misuse of words. "Suggestions to Authors" should be read and reread by those preparing the descriptions. The following do's and don't's are based on critical reading of previously written stratigraphic descriptions --mine as well as those of others.

Make only positive statements. No need to say non-calcareous, non-fossiliferous or non-oolitic in the final description though it is important to record such observations in the field.

Avoid expressions indicating transitions when locus of transition is not defined. Instead of saying "soft to hard" say, e.g., "soft in lower 0.4', hard in upper 0.6'" (for observed gradations in hardness) or "medium hard" if hardness is uniform and statement is meant to indicate a hardness intermediate between soft and hard. Similarly, say "grayish-brown" instead of gray to brown, or "gray to brown," or "gray and brown" if unit contains both colors. If a comparative expression is required, be sure that its elements are comparative. Instead of saying "plastic to silty" say "clayey to silty" or "plastic to earthy" (depending upon whether you wish to describe range in grain size or in hardness).

Don't give incomplete descriptions--"grayish-brown mottled at top" implie through the word "mottled", that the unit has more than one color but only one is stated.

Be careful in your usage of words. Degree of abundance or quality should be expressed by descriptive terms rather than by idioms or colloquial expressions which are apt to be ambiguous. The description "fine limestone" implies that the limestone is one of the best in the west, but the term "fine-grained" would better describe a Phosphoria limestone. An "iron-concretion" or "iron-coating" would call for wider notice than a description in a stratigraphic section would receive and in the latter these features would better be

described as a "limonite concretion" or, inasmuch as the identity of the mineral will generally not be known from field examination, as a "strong brown coating." The description "sandstone: makes heavy bench" is probably clear, but would be equally correct if meant to describe its potentialities for use as a park bench. "Heavy bedded" similarly describes a property not actually intended by the author. "Band" and "streak" refer to two dimensional features and should not be used in place of "layer" or "bed."

Some words admit no variation. "Unique," "sharp," "abrupt," can be nothing but unique, sharp, or abrupt. No "very's" or "slightly's" are allowed.

If you wish to liken the unit to another, say "like bed ---" or "similar to ---," not "same as bed ---" or "as bed ---." "Same" implies duplication through faulting. Use "overlying" or "underlying" instead of "preceding" or "following" when referring to an adjacent bed. Use the term "interbedded" rather than "present" in the description "mudstone: calcareous, light greenish-gray; some red shale present." Use "interbedded" or "interlaminated" instead of "intermingled" when describing an alternation of layers.

"A preposition should not be used to end a phrase with," and should not be used as a verb. Instead of "mudstone: black, with phosphatic brachiopods," say "mudstone: black; contains phosphatic brachiopods." Instead of "mudstone: black, with strong brown stains along joints," say "mudstone: black; strong brown stains along joints." Where possible use adjectives or adverbs instead of verbs in the description. "Siltstone: exhibits spheroidal weathering," would be more simply stated as "siltstone: spheroidally weathered."

The errors in the following published descriptions should be evident: "sandstone: red, cliff-former"; "siltstone: buff, soft, a few fossils"; "limestone: looks as though it is in place, but this not sure"; "shale: silty, dark brick-red, an inconspicuous gray bed in middle" (gray bed not only thin but modest--or was the author only sharp in spotting it?).

Columnar sections

The columnar sections (pp. 38 and 39) will be plotted on tracing cloth and will be a concise assemblage of all or nearly all of the basic data. They will be published or at least placed on open file as soon as all the data, including analyses, are gathered together. As the field descriptions will be modified by information provided by petrographic study and analytical work, two drafts will likely be prepared of each section. The first can, therefore, be rough and should be prepared in the field.

Written description

The columnar sections will contain essentially the same title, heading, and rock descriptions as the written log, though the description of some units may require condensation and many words will require abbreviation. The thickness of bedding and the size of the largest fragments will be given in separate columns, and the reaction to concentrated HCl will be expressly stated in a separate column as weak (equivalent to slight, faint, very slight); moderate (equivalent to medium); strong (equivalent to violent, very strong).

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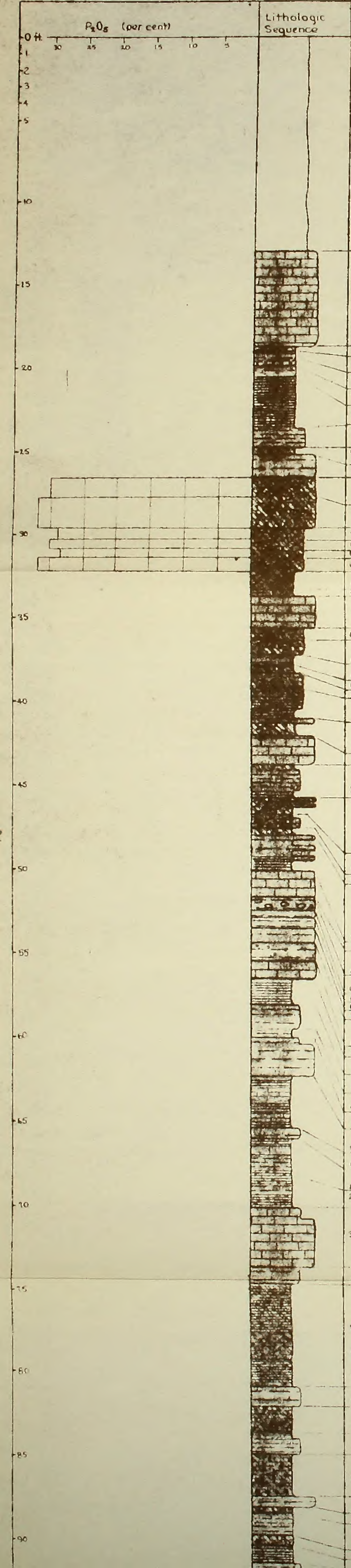
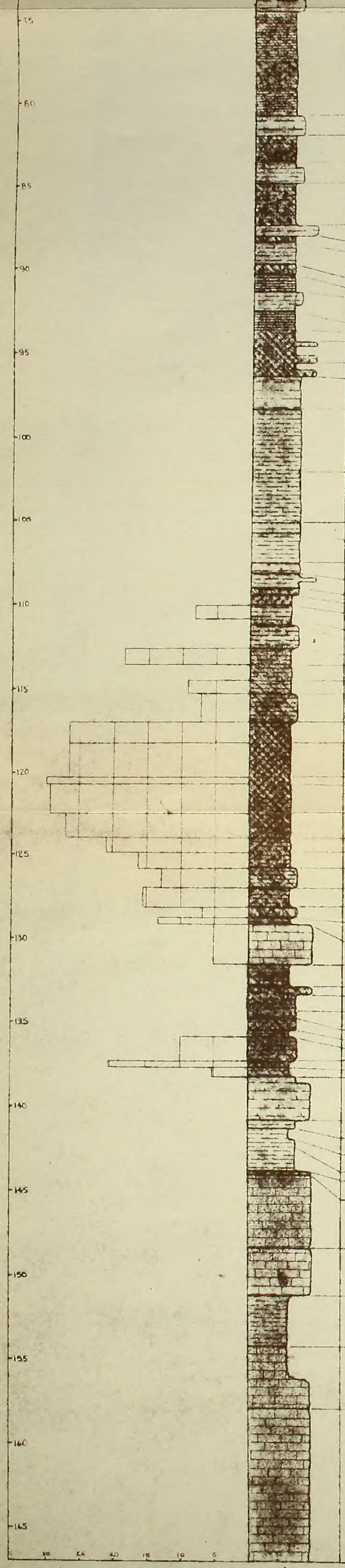


Thickness (Feet)	Description	Reaction to conc. HCl	Bed No	Sample No	P_2O_5	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	H_2O-	H_2O+	CO_2	F	Total S as SO_3	V_2O_5	TiO_2	Loss thru ignition	Acid insoluble
13	Covered																				
5.7	Limestone: dolomitic, hard, black, massive	strong	P-106	DML-9-47																	
0.3	Phosphate rock: finely oolitic, soft, black, thin-bedded.	mod.	P-105	DML-8-47																	
0.4	Mudstone: micaceous, soft, brownish-black, thin-bedded; grades from mudstone below. Fos. Coll. no. 47 HW 46	none	P-104	DML-7-47																	
0.5	Mudstone: micaceous, soft, brownish-black, thin-bedded; grades from mudstone below; lower 0.2' oolitic and slightly calcareous.	none to weak	P-103	DML-6-47																	
0.5	Mudstone: slightly micaceous, soft, brownish-black, thin-bedded; grades from mudstone below, slightly calcareous at top.	weak to none	P-102	DML-5-47																	
9.2	Mudstone: slightly micaceous, soft, brownish-black, fissile; grades from mudstone below; slightly calcareous in upper part.	weak to none	P-101	DML-4-47																	
1.2	Mudstone: micaceous, medium hard, brownish-black, thin-bedded; grades from phosphate rock below.	none	P-100	DML-3-47																	
0.4	Phosphate rock: finely oolitic, argillaceous, soft, black, fissile; grades from mudstone below; micaceous, more coarsely oolitic and slightly calcareous in upper part. Fos. coll. no. 47 HW 45.	mod. weak	P-99	DML-2-47																	
1.4	Mudstone: micaceous, slightly calcareous, hard, brownish-gray, thick-bedded. Fos. coll. no. 47 HW 44.	weak	P-98	DML-1-47																	
	Upper phosphate zone																				
1.1	Phosphate rock: coarsely oolitic, micaceous, hard, dark-gray, thin-bedded; upper 0.3 ft brownish-black and argillaceous.	mod.	P-97	2063	29.8	9.91	1.4	0.8	46.2	0.69	0.83	0.60			5.29	3.15	1.53	0.07	0.09	6.2	8.2
1.9	Phosphate rock: coarsely oolitic, hard, black, thick-bedded.	mod.	P-96	2062	32.9	4.73	0.9	0.6	49.1	0.61	1.01	0.39			2.31	3.5	1.84	0.10	0.07	5.4	7.2
0.7	Phosphate rock: finely oolitic, slightly micaceous, medium hard, dark-gray, thin-bedded.	weak none	P-95	2061	27.2	13.87	2.3	1.1	39.8	0.75	0.76	1.10			1.52	2.84	[illegible]	0.23	[illegible]	8.6	7.2
0.6	Phosphate rock: finely oolitic, medium hard, dark-gray to black, thin-bedded.	weak	P-94	2060	29.8	8.85	1.5	0.8	44.1	0.72	1.05	0.67			2.17	3.40	2.3	0.24	0.07	5.0	[illegible]
0.5	Phosphate rock: finely oolitic, slightly micaceous, medium hard, dark-gray to black, thin-bedded.	weak	P-93	2059	26.9	13.26	[illegible]	1.0	39.7	0.74	0.91	0.92			1.64	2.90	2.53	0.24	0.12	3.6	[illegible]
0.8	Phosphate rock: finely oolitic, medium hard, dark-gray, thin-bedded; grades from phosphate rock below.	weak	P-92	2058	32.1	6.49	1.2	0.6	45.7	0.61	1.16	0.53			1.70	3.49	2.37	0.15	0.05	6.9	[illegible]
1.1	Phosphate rock: finely oolitic, micaceous, soft, brownish-black, thin-bedded; grades from mudstone below; more coarsely oolitic upward.	weak none	P-91	VEM-61-47																	
0.4	Mudstone: micaceous, soft, brownish-black, massive.	none	P-90	VEM-60-47																	
1.9	Limestone: hard, grayish-brown, massive, upper 0.2 ft argillaceous, less calcareous, brownish-black.	strong	P-89	VEM-59-47																	
0.7	Phosphate rock: finely oolitic, medium hard, brownish-black, thin-bedded	weak	P-88	VEM-58-47																	
0.9	Phosphate rock: coarsely and medium coarsely oolitic, medium hard, black, thin-bedded. Contains phosphatic (?), medium coarsely oolitic, hard, dark-gray limestone lens 0.0-0.3 ft thick, not sampled.	mod.	P-87	VEM-57-47																	
0.6	Mudstone: slightly calcareous, soft, brownish-black, thin-bedded. Contains a few 0.01 ft layers of finely oolitic phosphate rock.	weak	P-86	VEM-56-47																	
0.5	Phosphate rock: medium coarsely oolitic, soft, brownish-black, thin-bedded	none	P-85	VEM-55-47																	
0.9	Phosphate rock: medium coarsely to very coarsely oolitic, medium hard, dark-gray and black, thick-bedded	mod.	P-84	VEM-54-47																	
1.8	Phosphate rock and phosphatic mudstone: 0.4 ft finely oolitic, soft, black, thin-bedded phosphate rock; overlain by 0.5 ft very finely oolitic, phosphatic, medium hard, brownish-black, thin-bedded mudstone; overlain by 0.9 ft very finely oolitic, phosphatic, medium hard, brownish-black, thin-bedded mudstone.	weak none	P-83	VEM-53-47																	
1.0	Phosphate rock, limestone, and mudstone: 0.5 ft very coarsely oolitic, crumbly, calcareous (?), black (some oolites light-gray), thick-bedded fossiliferous phosphate rock; overlain by 0.3 ft medium coarsely oolitic, crumbly, black, thick bedded, phosphate rock; overlain by 0.1 ft soft, brownish-black, thin-bedded mudstone, overlain by 0.1 ft hard, grayish-brown, thin-bedded limestone.	strong none weak strong	P-82	VEM-52-47																	
1.7	Limestone: hard, dark-gray, massive. Dusky-yellow coatings on joints. Fos. coll. no. 47 HW 43.	strong	P-81	VEM-51-47																	
2.0	Mudstone and phosphate rock: 0.4 ft micaceous, soft, brownish-black, fissile mudstone, overlain by 1.35 ft slightly calcareous, medium hard, brownish-black, thin-bedded mudstone, overlain by 0.25 ft finely to coarsely oolitic, crumbly, black, thick-bedded phosphate rock.	none	P-80	VEM-50-47																	
1.0	Phosphate rock and limestone (listed from oldest to youngest): 0.1 ft finely to coarsely oolitic, crumbly, black (wet), thin-bedded phosphate rock; 0.1 ft finely to coarsely oolitic, calcareous, crumbly, black, thin-bedded phosphate rock; 0.1 ft finely to coarsely oolitic, crumbly, black, thin-bedded phosphate rock; 0.2 ft micaceous, soft, brownish-black, fissile mudstone; 0.1 ft argillaceous, hard, dark-gray (dusky-yellow weathered), limestone; 0.1 ft finely to coarsely oolitic, crumbly, black phosphate rock; 0.1 ft argillaceous, hard, dark-gray limestone; finely to coarsely oolitic, crumbly, black phosphate rock.	Limestone: strong Phos. rock: none	P-79	VEM-49-47																	
0.8	Mudstone: lower 0.6 ft finely oolitic, phosphatic, medium hard, brownish-black (wet), thin-bedded, grades from mudstone below; upper 0.1 ft soft, more thin-bedded.	weak none	P-78	VEM-48-47																	
0.4	Phosphate rock: medium coarsely oolitic, crumbly, black, thin-bedded.	none	P-77	VEM-47-47																	
2.1	Mudstone and phosphate rock: (listed from oldest to youngest), 0.5 ft soft, black, fissile mudstone; 0.1 ft finely oolitic, phosphatic, black, fissile mudstone; 0.3 ft calcareous, hard, grayish-brown, thick-bedded mudstone; 0.3 ft soft, black, fissile mudstone; 0.3 ft calcareous, hard, grayish-brown, thick-bedded mudstone; 0.05 ft finely oolitic, phosphatic, soft, black, fissile mudstone; calcareous, hard, grayish-brown, thin-bedded mudstone; 0.05 ft finely oolitic, soft, black, fissile phosphate rock; 0.05 ft calcareous, hard, grayish-brown, thin-bedded mudstone; 0.05 ft finely oolitic, soft, black, fissile phosphate rock; 0.3 ft calcareous, hard, grayish-brown, thick-bedded mudstone.	calc. ms: strong others: none	P-76	VEM-46-47																	
1.6	Hanging-wall limestone: hard, brownish-gray, massive. Fos. coll. No. 47 HW 42.	strong	P-75	VEM-45-47																	
	Vanadiferous zone																				
0.2	Mudstone: hard, black, thick-bedded. Contains five 0.01 ft laminae of finely oolitic phosphate rock in lower 0.1 ft.	none	P-74	VEM-44-47																	
0.55	Mudstone: hard, black, thick-bedded. Contains phosphatic elliptical nodules up to in diameter on lower surface.	none	P-73	VEM-44-47																	
0.4	Mudstone: hard, black, thin-bedded; 0.02 ft calcite vein along lower contact	none	P-72	VEM-43-47																	
0.65	Mudstone: hard, black, thick-bedded.	none	P-71	VEM-42-47																	
0.9	Mudstone: hard, black, thick-bedded.	none	P-70	VEM-41-47																	
1.05	Mudstone: hard, black, thick-bedded but composed of alternating 0.005 ft to 0.01 ft laminae of calcareous mudstone and finely oolitic, phosphatic (?), calcareous, mudstone.	mod.	P-69	VEM-40-47																	
1.1	Footwall limestone: hard, brownish-gray (wet), thick-bedded, fossiliferous. Fos. coll. No. 47 HW 35	mod.	P-68	VEM-39-47																	
1.5	Mudstone: micaceous, soft, black (wet), fissile; grades from mudstone below. Strong yellow coating on lower 0.2 ft.	none	P-67	VEM-38-47																	
1.4	Mudstone: medium hard, brownish-black (wet), massive, upper 0.4 ft soft, thin-bedded. Yellowish-white and very pale-brown coatings on joint surfaces.	none	P-66	VEM-37-47																	
0.5	Mudstone: soft, brownish-black (wet), thin-bedded, upper 0.1 ft very finely oolitic. Dusky-reddish-brown and moderate yellow coatings on joint surfaces.	none	P-65	VEM-36-47																	
2.3	Limestone: argillaceous, granular, hard, brownish-black (wet), massive in lower 1.4 ft, thick-bedded in upper 0.9 ft; upper 0.25 ft more argillaceous and medium hard. Yellowish-white coatings on joints.	strong	P-64	VEM-35-47																	
3.0	Mudstone and limestone: eight, soft, black (wet), fissile mudstone layers 0.2 ft to 0.1 ft thick interbedded with seven argillaceous, brownish-black (wet), thin-bedded limestone layers 0.05-0.15 ft. thick. Some mudstone layers are locally finely oolitic.	Limestone: strong ms: weak	P-63	VEM-34-47																	
0.7	Mudstone: calcareous, granular appearance, medium hard, brownish-black (wet), thick-bedded. Yellowish-white coating on joint surfaces.	mod.	P-62	VEM-33-47																	
2.0	Mudstone: finely oolitic, phosphatic (?), soft, black (wet), fissile mudstone interbedded with calcareous, hard, brownish-black (wet), thin-bedded mudstone. Contains hard, brownish-gray, massive limestone lens 0.0-0.8 ft thick, 1.4 ft below top, not sampled; lower contact irregular.	weak strong	P-61	VEM-32-47																	
2.0	Like VEM-32-47; grades from limestone below.	weak strong	P-61	VEM-31-47																	
3.5	Limestone: argillaceous, hard, brownish-gray (wet), thick-bedded and massive; black, less calcareous, medium hard in upper 0.6 ft, pale-yellow coatings. Thickness varies from 2.6 ft to 3.5 ft (may be a lens). Fos. coll. No. 1-9/9/47 (USN).	strong	P-60	VEM-30-47																	
1.1	Mudstone: calcareous, medium hard, black (wet), thick-bedded. Pale-yellow, yellowish-white and very pale-brown coatings on joints.	mod.	P-59	VEM-29-47																	
3.0	Mudstone (listed from oldest to youngest) 0.7 ft very finely oolitic, phosphatic (?), micaceous, soft brownish-black (wet) fissile mudstone, grades from mudstone below; 0.8 ft very finely oolitic, phosphatic, soft, black (wet) fissile mudstone 0.0-1.4 ft hard, brownish-black (yellowish-white coatings on joint surfaces), limestone lens-included in single 0.5 ft very finely oolitic, phosphatic, soft, black, fissile mudstone, 0.2 ft calcareous, soft black, thin-bedded mudstone; 0.6 ft very finely oolitic, phosphatic, soft, black mudstone.	weak	P-58	VEM-28-47																	
1.6	Mudstone: very finely oolitic, phosphatic, calcareous, soft, black (wet), thin-bedded; lower contact wavy. Thickness varies from 1.6 ft to 2.2 ft (may be a lens). Yellowish-white coating on joint surface.	mod.	P-57	VEM-27-47																	
1.0	Mudstone: very finely oolitic, phosphatic, soft, black, fissile.	none	P-56	VEM-26-47																	
1.2	Mudstone: calcareous, medium hard, brownish-black (wet), thick-bedded, very finely oolitic in upper 0.2 ft. Yellowish-white coating on joint surfaces.	mod.	P-55	VEM-25-47																	
1.6	Mudstone: very finely oolitic, phosphatic, soft, black (wet), thin-bedded, grades from calcareous mudstone below.	weak	P-54	VEM-24-47																	
1.3	Mudstone: calcareous, medium hard, brownish-black (wet), thin-bedded, upper 0.2 ft more thin-bedded, soft. Yellowish-white coatings on joint surfaces.	mod.	P-53	VEM-23-47																	
2.5	Mudstone and phosphate rock: about forty 0.01-0.2 ft layers of alternating medium coarsely oolitic, crumbly, black (wet), thin-bedded phosphate rock and medium coarsely oolitic, phosphatic, soft, black mudstone; lower 0.1 ft finely and coarsely pisolitic.	none to weak	P-52	VEM-22-47																	
0.7	Mudstone: calcareous, hard, brownish-black (wet), thick-bedded. Yellowish-white coatings on joint surfaces. 0.2 ft layer very coarsely oolitic phosphate rock 0.15 ft below top.	mod.	P-51	VEM-21-47																	
0.3	Phosphate rock: coarsely oolitic, crumbly, black (wet), thin-bedded. Upper 0.1 ft nodular.	weak	P-50	VEM-20-47																	
1.3	Mudstone: soft, brownish-black (wet), thin-bedded, yellowish-white coatings on joint surfaces; lower 0.3 ft slightly phosphatic, finely oolitic, upper 0.4 ft slightly calcareous. Fault (strikes N. 10° W., dips 60° E.) truncates beds 49 and 50.	weak none	P-49	VEM-19-47																	
0.6	Phosphate rock: finely to very coarsely oolitic, crumbly, black, thin-bedded.	weak	P-48	VEM-18-47																	
1.1	Mudstone: slightly calcareous, soft																				



1.1	Mudstone calcareous, medium hard, [illegible] pale-brown coatings on joints	mod.	P-59	VEM-29-47																	
3.0	Mudstone (listed from oldest to youngest) 0.7 ft very finely oolitic, phosphatic (?), micaceous, soft brownish-black (wet) fissile mudstone, grades from mudstone below; 0.6 ft very finely oolitic, phosphatic soft black (wet) fissile mudstone; 0.4-0.6 ft hard, brownish-black (yellowish-white coatings on joint surfaces), limestone lens included in sample; 0.5 ft very finely oolitic, phosphatic, soft, black, fissile mudstone; 0.2 ft calcareous soft black thin-bedded mudstone; 0.6 ft very finely oolitic, phosphatic, soft, black mudstone.	weak	P-58	VEM-28-47																	
1.8	Mudstone very finely oolitic, phosphatic, calcareous, soft black (wet), thin-bedded; lower contact wavy. Thickness varies from 1.6 ft to 2.2 ft (may be in line); yellowish-white coating on joint surfaces.	mod.	P-57	VEM-27-47																	
1.6	Mudstone very finely oolitic, phosphatic, soft, black, fissile.	none	P-56	VEM-26-47																	
1.2	Mudstone calcareous, medium hard, brownish-black (wet), thick-bedded, very finely oolitic in upper 0.2 ft. Yellowish-white coating on joint surfaces.	mod.	P-55	VEM-25-47																	
1.6	Mudstone very finely oolitic, phosphatic, soft, black (wet), thin-bedded, grades from calcareous mudstone below.	weak	P-54	VEM-24-47																	
1.3	Mudstone calcareous, medium hard, brownish-black (wet), thin-bedded, upper 0.2 ft more thin-bedded, soft. Yellowish-white coatings on joint surfaces.	mod.	P-53	VEM-23-47																	
2.5	Mudstone and phosphate rock: about forty 0.01-0.2 ft layers of alternating medium coarsely oolitic, crumbly, black (wet), thin-bedded phosphate rock and medium coarsely oolitic, phosphatic, soft black mudstone; lower 0.1 ft finely and coarsely pisolitic.	none to weak	P-52	VEM-22-47																	
0.7	Mudstone calcareous, hard, brownish-black (wet), thick-bedded. Yellowish-white coatings on joint surfaces. 0.2 ft layer very coarsely oolitic phosphate rock 0.5 ft below top.	mod.	P-51	VEM-21-47																	
0.3	Phosphate rock coarsely oolitic, crumbly, black (wet), thin-bedded. Upper 0.1 ft nodular.	weak	P-50	VEM-20-47																	
1.3	Mudstone soft, brownish-black (wet), thin-bedded, yellowish-white coatings on joint surfaces; lower 0.3 ft slightly phosphatic, finely oolitic; upper 0.4 ft slightly calcareous. Fault (strikes N. 10° W., dips 60° E.) truncates beds 49 and 50.	weak none	P-49	VEM-19-47																	
0.6	Phosphate rock finely to very coarsely oolitic, crumbly, black, thin-bedded.	weak	P-48	VEM-18-47																	
1.1	Mudstone slightly calcareous, soft, black (wet), fissile.	weak	P-47	VEM-17-47																	
1.1	Mudstone calcareous, soft, brownish-black (wet), thick-bedded; yellowish-white coatings on joint surfaces; upper 0.1 ft medium hard, more calcareous. Thickness varies from 1.1-1.5 ft. Beds forms the part of the roof and east wall of old coal (?) prospect adit.	mod.	P-46	VEM-16-47																	
1.1	Mudstone soft, black (wet), fissile and thin-bedded; weak-yellow coatings on joint surfaces.	none	P-45	VEM-15-47																	
0.8	Phosphate rock finely to coarsely oolitic, crumbly, black, thin-bedded, grades from phosphate rock below.	mod.	P-44	VEM-14-47																	
1.3	Phosphate rock medium coarsely oolitic, crumbly black, lower 0.45 ft and upper 0.25 ft finely oolitic and brittle, grades from phosphate rock below.	weak mod.	P-43	LES-10-47																	
0.7	Phosphate rock medium-coarsely, lower half brittle, upper half crumbly, oolitic, black, grades from mudstone below. Forms west wall of adit.	weak strong	P-42	LES-9-47																	
2.0	Mudstone medium hard, brownish-gray, massive, upper 0.6 ft medium-coarsely oolitic.	mod.	P-41	LES-8-47																	
3.8	Mudstone slightly calcareous, medium hard, brownish-black, arbitrarily separated from LES-6-47	mod.	P-40	LES-7-47																	
3.0	Mudstone slightly calcareous, medium hard, brownish-black, thin-bedded, grades from mudstone below. Yellowish-white coatings on joints	weak	P-39	LES-6-47																	
0.6	Mudstone medium hard, brownish-black, thick-bedded in lower 0.4 ft, thin-bedded in upper 0.2 ft, thickness varies from 0.6 ft to 0.7 ft	weak	P-38	LES-5-47																	
1.8	Mudstone medium hard, brownish-black, thin-bedded (moderately fissile in upper part), grades from mudstone below. Yellowish-white coatings on joint surfaces - abundant in lower half	mod.	P-37	LES-4-47																	
0.6	Mudstone moderately calcareous, micaceous, medium hard, brownish-black, thick-bedded. Yellowish-white coatings on joint surfaces.	mod.	P-36	LES-3-47																	
0.9	Mudstone moderately calcareous, micaceous, medium hard, brownish-black; thin-bedded in lower and upper parts, thick-bedded, more strongly calcareous, hard in middle. Yellowish-white coatings on joint surfaces.	mod. strong	P-35	LES-2-47																	
0.4	Mudstone very finely oolitic, phosphatic, medium hard, black, thin-bedded. Yellowish-white coatings on joints.	weak	P-34	LES-1-47																	
0.2	Phosphate rock very finely oolitic, soft, black (wet), thin-bedded in lower part, thick-bedded in upper part.	none	P-33	VEM-13-47																	
0.8	Mudstone and phosphate rock: lower 0.5 ft soft, black, thin-bedded mudstone, containing weak reddish-brown coatings on joint surfaces; upper 0.3 ft finely oolitic, soft, black phosphate rock.	none	P-32	2087	8.1	44.45	3.0	2.4	12.1	0.93	0.30	2.13			0.77	2.68	2.81	0.35	0.40	19.6	40.9
0.4	Mudstone very finely oolitic, phosphatic, soft, black (wet), thin-bedded, fissile in upper 0.15 ft.	none	P-31	2086																	
1.4	Mudstone calcareous, medium hard, brownish-black (wet); non-calcareous in lower 0.3 ft, dusky-brown in upper 0.5 ft, yellowish-white coatings on joint surfaces in lower 0.9 ft, especially prominent in lower 0.1 ft.	weak to mod.	P-30	2085																	
1.0	Mudstone phosphatic, soft, black (wet), thin-bedded; fissile in middle 0.1 ft.	none	P-29	2084	18.1	30.01	2.0	1.6	27.2	3.82	0.86	1.81			1.40	1.85	0.60	0.42	0.33	11.6	33.3
0.9	Mudstone phosphatic, micaceous, soft, black (wet), thin-bedded, fissile in upper 0.5 ft.	none	P-28	2083																	
0.8	Mudstone phosphatic, soft, black (wet), thin-bedded, grades from calcareous mudstone below	weak	P-27	2082	9.0	36.28	2.4	1.6	21.5	4.93	1.10	2.03			1.15	0.88	0.35	0.23	0.36	16.1	40.2
1.7	Mudstone calcareous, phosphatic, medium hard, brownish-black, thick-bedded; thin-bedded and less calcareous in upper and lower 0.2 ft; grades from phosphate rock below.	mod.	P-26	2081	1.3	22.93	1.3	1.2	26.7	9.12	1.02	1.30			24.55	0.66	0.85	0.18	0.23	2.7	25.5
1.2	Phosphate rock very finely oolitic, soft, black (wet), thin-bedded. Grades from phosphate rock below.	none to slight	P-25	2080	26.3	15.75	2.1	1.0	41.5	0.79	0.95	1.35			0.26	2.55	1.71	0.30	0.16	9.4	14.6
2.1	Phosphate rock very finely oolitic, soft, brownish-black (wet), thin-bedded; yellowish-gray coatings along joints. 0.0-0.25 ft hard, brownish-gray dolomite lens 1.4 ft above base.	weak	P-24	2079	26.1	14.06	1.6	0.7	39.7	1.83	0.77	1.36			4.90	2.54	1.81	0.17	0.13	9.3	13.6
0.3	Phosphate rock very finely oolitic, soft, black (wet), thin-bedded.	weak	P-23	2078	29.5	13.04	1.1	0.6	47.9	0.77	0.72	0.99			2.79	2.91	1.26	0.08	0.10	7.1	10.9
1.7	Like 2076	weak	P-22	2077	26.6	11.63	1.4	0.6	42.3	0.73	0.90	0.68			3.33	2.86	1.89	0.09	0.10	42.3	10.5
1.7	Phosphate rock very finely oolitic, soft, black (wet), thin-bedded, grades from mudstone below. Yellowish-gray coatings on joint surfaces.	weak	P-22	2076	26.7	13.36	1.2	0.7	41.2	0.47	0.95	1.07			3.97	2.77	2.13	0.14	0.12	9.1	12.3
0.8	Like 2074	weak	P-21	2075	21.1	18.16	2.0	1.0	35.4	1.02	0.83	1.51			6.15	2.36	2.51	0.10	0.16	14.2	18.5
0.9	Mudstone finely oolitic, phosphatic, soft, black, thin-bedded. Yellowish-gray on joint surfaces.	weak	P-21	2074	16.4	22.77	2.2	1.1	30.4	3.74	0.70	1.88			9.40	1.76	1.82	0.07	0.21	14.7	24.4
1.2	Mudstone phosphatic, slightly calcareous, medium hard, brownish-black. Light yellowish-gray coatings on joint surfaces.	weak	P-20	2073	12.8	25.87	2.8	1.2	27.8	5.23	0.60	1.53			12.08	1.40	1.64	0.08	0.21	17.1	26.0
1.1	Mudstone very finely oolitic, phosphatic, soft, black (wet), thin-bedded; grades from limestone below	mod. weak	P-19	2072	15.6	25.91	2.7	1.2	29.4	5.42	0.63	2.26			8.52	1.80	2.31	0.06	0.21	14.0	27.3
0.7	Limestone: argillaceous, phosphatic, medium hard, brownish-black, thick-bedded. Upper 0.2 ft calcareous. Light yellowish-gray coatings on joint surfaces.	strong	P-18	2071	6.2	21.20	2.0	0.9	36.3	9.84	0.30	2.29			23.53	0.76	1.07	0.06	0.11	26.5	23.8
0.4	Mudstone slightly calcareous, phosphatic, soft, black (wet), thin-bedded; lower 0.15 ft very finely oolitic and moderately calcareous; upper 0.22 ft calcareous, plastic, light yellowish-brown clay.	weak mod.	P-17	2070	13.3	21.62	1.1	1.0	30.9	6.04	0.42	1.65			16.28	1.58	1.33	0.05 0.06	0.31	19.9	22.7
2.3	Limestone, argillaceous, hard, brownish-black (wet), thick-bedded; 0.1 ft layers of medium coarsely oolitic, black phosphate rock 1.0 ft and 1.6 ft above base. Lower contact slightly discordant.	mod.	P-16	2069	5.2	16.21	1.2	0.6	35.2	3.60	1.33	0.79			29.97	0.49	0.91	0.05 0.06	0.19 0.08	32.6	16.1
1.5	Mudstone: phosphatic (?), calcareous, soft, black (wet), thin-bedded.	weak	P-15	VEM-12-47																	
0.5	Mudstone finely oolitic, phosphatic, calcareous, hard, brownish-gray, thick-bedded. Grades from mudstone below.	mod.	P-14	VEM-11-47																	
0.9	Mudstone finely oolitic, phosphatic, calcareous, medium hard, brownish-black (wet), massive; grades from mudstone below. Less oolitic in upper part.	mod.	P-13	VEM-10-47																	
0.5	Mudstone finely to coarsely oolitic, phosphatic, calcareous, medium hard, brownish-black (wet), thick-bedded; grades from phosphate rock below. Light yellowish-gray coating on joint surfaces.	mod.	P-12	VEM-9-47																	
0.7	Phosphate rock finely oolitic, medium hard, black (wet), thin-bedded.	weak	P-11	VEM-8-47																	
0.4	Mudstone finely oolitic, phosphatic, soft, black (wet), fissile.	none	P-10	VEM-7-47																	
1.4	Mudstone calcareous, phosphatic, medium hard, black (brownish-gray weathered), thin-bedded.	mod.	P-9	2066	9.7	17.98	2.4	1.4	26.8	9.97	0.42	1.31			21.25	0.79	2.17	0.09	0.14	25.6	20.0
0.4	Phosphate rock finely oolitic, soft, black, thin-bedded.	weak	P-8	2065	20.6	26.27	3.2	1.6	31.1	1.03	0.79	1.58			3.28	2.26	1.80	0.17	0.19	9.0	26.9
0.5	Mudstone micaceous, soft, black, thin-bedded; strong brown coatings on joint surfaces; grades from mudstone below.	none	P-7	2064	5.5	55.29	4.2	3.6	5.1	0.67	0.59	3.96			0.80	0.40	3.30	0.36	0.45	11.5	62.7
2.6	Mudstone calcareous, micaceous, hard, brownish-black, thick-bedded; medium hard, moderately calcareous in upper 0.35 ft. Very pale-brown coatings on joints. Grades from mudstone below.	weak to mod.	P-6	VEM-6-47																	
0.5	Mudstone micaceous, medium hard, brownish-black, thick-bedded; grades from mudstone below. Yellowish-white coatings on joint surfaces.	mod.	P-5	VEM-5-47																	
0.6	Mudstone micaceous, soft, black, thin-bedded; grades from mudstone below. Dark reddish-brown coatings on joint surfaces in upper half, reddish-brown and light olive coatings below.	none	P-4	VEM-4-47																	
0.5	Mudstone: medium hard, black, thin-bedded; grades from mudstone below. Dark reddish-brown and moderate yellow coatings on joint surfaces.	none	P-3	VEM-3-47																	
1.4	Mudstone slightly micaceous, medium hard, brownish-black, thin-bedded. Light yellowish-gray on joint surfaces.	weak	P-2	VEM-2-47																	
0.2	Phosphate rock: coarsely oolitic, hard, black (pale-brown weathered), thick-bedded. No bedding plane (i.e. crack) between this bed and Wells formation below.	weak	P-1	VEM-1-47																	
	WELLS FORMATION																				
4.3	Limestone: finely crystalline, finely sandy, hard, medium gray (very pale-brown weathered), thick-bedded	mod.	W-1	not sampled																	
2.8	Limestone: finely crystalline, hard, light brownish-gray and brownish-gray, thick-bedded.	mod.	W-2	not sampled																	
3.0	Siltstone: finely sandy, calcareous, soft, pale brown, thin-bedded.	not determined	W-3	not sampled																	
3.8	Limestone: sandy, hard in lower half, soft in upper half, light gray, thick-bedded	not determined	W-4	not sampled																	
9.0+	Limestone: hard, brownish-gray (light-gray weathered), thick-bedded. Interval, largely covered to top of unit formerly mapped as Weber quartzite.	not determined	W-5	not sampled																	

Section measured by V.E. McKelvey, D.M. Larrabee and L.E. Smith in June 1947. Sampled by V.E. McKelvey in June 1946 (numbers 2058-2087) and by R.A. Gulbrandsen in June 1947 (all others).

Character and composition of rocks of the PHOSPHATIC SHALE MEMBER OF THE PHOSPHORIA FORMATION, COAL CANYON, WYOMING

Sec. 7, T. 26 N., R. 119 W., Lincoln County, Wyo., on east limb of Sublette anticline. Samples VEM-40-44 from vanadiferous zone in face of adit 50 feet above canyon bottom on north side; all others from trench at bottom of canyon on south side. Beds strike N. and dip 75° east.

Chemical analyses made by P.C. Gwinn, R.H. Davis, E.H. Briggs and Marjorie Smith, under the supervision of F. J. Gray, Tennessee Valley Authority.

Words may be abbreviated freely but the abbreviations ought to be uniform. The attached list, pp. 42-44, suggests standard abbreviations and can be modified or expanded as others suggest. Where lack of space prevents describing an alternation of rock types occurring in one unit, lump them together and give total thickness of each rock type, its description, and the average thickness of the layers.

As the number of analyses that will be made on the samples from different sections will vary from few to many, it will be well to make the paper wide enough to accommodate about 30 analyses, but to ink in columns for only five.

Graphic section

The graphic plot of the section is its most important part, for it is the visual abstract of the section on which correlations (hence reserve estimates) will ultimately be based. It is important, therefore, to show as many characteristics as possible of the various rock types without obscuring them.

The sections will be plotted on a scale of 1 inch equals 5 feet. As they should not be longer than about 40 inches, the Rex and the lower portion of the Dinwoody will have to be plotted on one page and the phosphatic shale and Wells on another if all have been measured. The width of the column should be 0.5 inch to 0.7 inch (0.5 for soft beds, 0.6 for medium hard, and 0.7 for hard).

To facilitate the drafting of the sections, lithologic symbols have been prepared and printed on wax cellophane. The meaning of the symbols is shown on an explanation attached to the sheet of symbols. It will be apparent that many of them are to be used in combination with others. Two symbols commonly used in combination (4 thin bedded mudstone, and 26 moderately oolitic; and 7 shale, and 26) have already been combined in the printed symbols (31 and 32). Because each symbol is numbered, the geologist can write the appropriate number or numbers on the blank column in blue pencil and the draftsman can lay the patterns.

The P_2O_5 and V_2O_5 content will be shown as a bar graph on the left side of the lithologic column. The body of the graph will consist of vertical lines spaced so that each line indicates 5 percent P_2O_5 and 0.1 percent V_2O_5.

Correlation charts

Correlation charts will show the continuity and lateral variations of individual layers of the sections measured. As many economic and scientific deductions will be drawn from them, their preparation is very important.

The lines or directions along which the correlations are to be made must be selected first and with considerable care. Generally, within a given area, a number of charts or lines of correlations will be required and these should be oriented so as to show the direction of the most significant lateral variations in lithology and, in contrast, the directions of least lateral variations. Generally this will be achieved best by having intersecting lines of correlations. In southeastern Idaho and western Wyoming, at least, lines of correlation extending in an east-west direction will show greatest lithologic variation and north-south lines will show greatest lithologic continuity.

Because it is desirable to have the correlation lines as nearly straight as possible (and not to zig-zag over the country) the correlation lines will have to be shuffled around a good deal in order to make the best selection of sections to include on the various charts. It is helpful to cut out the lithologic column from the columnar sections and to experiment with mock charts until the arrangement best showing the desired features is achieved. A section common to two lines of correlation should be shown at their intersection.

The columnar sections on a line of correlation should be spaced to scale. A mile to the inch is a good horizontal scale for most of our charts, but larger or smaller scales may be required in places. The vertical scale generally will be five feet to the inch, but likewise can be varied if need be. Both vertical and horizontal scales should be the same on all charts of a given series.

The sections should be lined up on a datum which can be any horizon but should be one that can be recognized over the region and should be in that portion of the section showing the least lateral variation in lithology. In southeastern Idaho and western Wyoming the contact between the phosphatic shale and the Rex best meets the datum requirements and will be used for that purpose on our correlation charts there.

The body of the chart will consist of graphic columnar sections without any written description. The P_2O_5 bar graph will be omitted, however, and the P_2O_5 content shown by the phosphate rock symbol on the section itself and in numbers along the right-hand margin. The V_2O_5 content will be shown graphically. It may be necessary to devise techniques to show content of other elements also and any suggestions for so doing will be gratefully received. The presence of fossils will be indicated by a large "F" along the right-hand margin and, if possible, the name of the fossil characterising the fauna will be stated.

Stratigraphic correlations between various sections will be shown in solid lines where the correlation is definite, and by dashed lines where the correlation is approximate. As many correlation lines should be shown as knowledge permits, though discretion will have to be exercised in places to avoid impairing legibility of the chart with closely spaced lines.

Wherever possible, the correlations should be checked in the field. This is best done on mock charts or on the columnar sections themselves in advance of the drafting of the chart, and should be done during or at the close of the field season in which the sections are measured, especially if the latter were exposed in trenches.

Each chart should, of course, include an index map showing the location of the sections shown on the chart, and showing also the correlation lines of other charts of the same series. Needless to say, each chart should include a complete explanation as well.

ABBREVIATIONS

A.

Appearance	app.
Approximate	approx.
Argillaceous	arg.
Arbitrary	arbit.
Average	av.

B.

Below	blw.
Black	blk.
Blue	bl.
Breccia(ted)	Brec('d).
Broken	brok.
Brown	brn.

C.

Calcareous	calc.
Centimeter	cm.
Chert	cht.
Cherty	chty.
Clay	cl.
Coarse	cs.
Coarsely	csly.
Concretion(s)	conc(s).
Conspicuous	conspic.
Crystal(line)	Xl(n)

D.

Dark	dk.
Diameter	diam.
Distinct	dst.
Dolomite	dol.

E.

Elongate(d)	elong(d).

F.

Fault(s)	flt(s).
Fine	f.
Fissile	fsl.
Fossil(s)	fos(s).
Fossiliferous	foslf.
Fracture(s)(d)	Fract(s)(d).
Fragment(s)	frag(s).
Friable	frbl.
Flattened	flat.

G.

Gradational	grdl.
Grade	grd.
Grain	gr.
Granule	gran.
Granular	gran'r.
Gray	gy.
Green	grn.

H.

Hard	hd.

I.

Indeterminate	indet.
Irregular	irreg.

L.

Laminated	lam.
Layer(s)	lyr(s).
Lenticular	lent.
Light	lt.
Limestone	ls.
Lithology(ic)	lith(c).
Lower	lwr.

M.

Massive	msv.
Material	mat.
Medium	med.
Micaceous	mic.
Millimeter	mm.
Moderate	mod.
Mudstone	ms.

N.

Negligible	negl.
Nodular	nodr.
Nodule(s)	nod(s).
Number(s)	no(s).

O.

oolite(s)	ool(s).
oolitic	oolt.

P.

Part	pt.
Partly	ptly.
Phosphate	phos.
Phosphatic	phost.
Pisolite(ic)	piso(c).
Plastic	plas.
Platy	plty.

R.

Reaction	react.
Rock(s)	rk(s).

S.

Shale(y)	shl(y).
Silt(y) (stone)	slt(y)(st).
Slight(ly)	sl(y).
Sphere(s)	sph(s).
Spheroid(s)	sphd(s).
Strong	str.

T.

Toward	twd.

U.

Upper	up.

V.

Very	v.

W.

Weak	wk.
With	w.

Y.

Yellow	yel.

Phrases

Not checked	n.c.
Not determined	n.d.
Not sampled	n.s.

June 20, 1961

Memorandum

To: Regional Geologist, Denver, Colorado

From: District Geologist, Salt Lake City, Utah

Subject: Phosphate sampling.

This discussion is linked with my previous memorandum on trenching. The two memos are a review of the report by V. E. McKelvey titled "Description and sampling of the rocks of the Phosphoria formation." That part of the following discussion included in quotation marks has been taken directly from McKelvey's report.

SAMPLING

The rocks exposed in each trench should be carefully described. Sampling may be restricted to phosphatic and vanadiferous intervals. Where the phosphatic intervals are not clearly defined or where there is doubt, the entire dark colored part of the Phosphoria formation should be sampled. It will not be necessary to sample the non-phosphatic rocks unless they lie between phosphatic beds and are less than the combined thickness of the adjacent phosphatic beds. Any sandstone in the Phosphoria formation should be carefully examined for phosphate content.

"The limits of each unit chosen for sampling should be marked by driving a ten-penny nail at the appropriate spot in the trench wall at the top and base of the unit. The number of the sample should be written on a shipping tag placed on the nail at the stratigraphic base of each sample."

Thickness of units to be sampled

In the phosphatic and vanadiferous intervals "separate samples should be collected from each lithologic unit 0.5 foot or more in thickness or from smaller units which occur as partings between lithologic units which are 0.5 foot or more thick; lithologic units less than 0.5 foot in thickness occurring in sequence can be grouped together and a thickness of 0.5-1.0 foot included in one sample. Lithologic units 5 feet or more in thickness should be divided into two or more parts, so that no more than 5 feet is included in one sample."

Nature and size of sample

"Each sample should be cut from a channel or bench 3-4 inches deep and 6-8 inches wide, which will produce 15 to 40 pounds of rock per foot of channel; the dimensions of the channel should be larger in rocks jointed in such a manner that the edges of a channel cut in them are jagged or irregular and can be smaller in rocks in which a relatively smooth-walled channel can be cut. The channel likewise should be larger where a sequence of samples is to be cut from thin units than where they are cut from thick units. No sample should weigh less than 12 pounds, regardless of how thin a unit it represents. Special care should be taken to see that the sample is representative of the unit from which it is taken. The channel can either be normal to the strike and dip or at an angle to either the strike or dip, depending upon the orientation of the trench with respect to the structure, as well as the type and degree of development of the jointing. The channel must be cut on a single plane, whatever its orientation may be, so as to obtain equal parts stratigraphically of the entire unit. If this cannot be done, the unit should be further subdivided into parts in each of which a channel and a separate sample can be cut in a single plane."

Numbering of samples

Beginning during the 1961 season, samples will be numbered consecutively, beginning with No. 1 and extending as high as necessary. If more than one party is used a series of numbers will be alloted to each. Each sample will be further distinguished by the initials of the man who collected it. Hand specimens should be given the same serial number as the channel sample but accompanied by a letter. Any additional hand specimens collected by field mapping personnel, etc. from intervals not sampled must be identified differently so as not to conflict with the sample numbering system. Each group of samples from a single trench will be assigned a lot number which may also serve as a trench number. The work of our Branch will be sufficiently similar to that already completed by the Geologic Division to establish a numbering system that will be compatible. Previous lot numbers have reached the 1400's. It is therefore suggested that our lot (trench) numbers start with 1500.

Crushing, quartering, and labelling

To reduce handling and the amount of material removed from each site the crusher and splitter will be brought to each trench site where possible. The material will be reduced to about 3½ pounds and placed in a quart carton or other suitable container. A label will be placed on top of the material in the carton and the top and side of the container will be marked showing the lot and sample numbers. The cartons may be placed in cardboard boxes showing the lot and sample numbers and be delivered to the Survey laboratory in Casper, Wyoming.

"If the trench is far from a road it may not be practical to transport samples away from the trench without crushing and splitting. In this case the rock fragments should be broken to minus one-quarter inch size, coned and quartered on a sampling canvas or in a Jones splitter until reduced to "about 3½ pounds" (in coning and quartering opposite quarters of the cone are retained and re-coned and re-quartered until reduced to the desired size)."

Hand specimens

A hand specimen of each rock unit in the trench should be collected. These may be placed in paper sample envelopes and assembled in sequence in cardboard tray boxes which allow access for later examination and ease of storage. The label (on outside of envelope) should show the distance above the base of the unit from which it came, the rock unit number, serial number if a channel sample was collected, the formation and geographic location.

Special sampling

At selected localities it will be appropriate to completely sample the units exposed in a trench for semi-quantitative spectrographic analyses. The objective is to augment the data already available from the Geologic Division program and gain a regional picture of the concentration of some of the trace elements and metals in the Phosphoria formation. This information will be of interest to the Branch of Mining Operations in addition to our own Branch. Since only a small amount of material will be required, the quartered material will be collected in paper sample envelopes and stored in special cardboard box trays in sequence. The envelopes and boxes should be marked "specs" for specific identification.

Oil shales have been noted in the phosphatic section, especially in southwestern Montana and that part of eastern Idaho north of the Snake River. At the discretion of the project chief channel samples should be collected for analysis in the same manner as for phosphate samples.

Distribution of samples

Samples for phosphate, vanadium, and oil analyses will go to the Survey laboratory in Casper, Wyoming. Samples for spectrographic analysis should be shipped to the Survey laboratory in Denver, Colorado. Hand specimens should be retained by the field party mapping the trench locality or forwarded to a storage center designated by the chief of the quadrangle mapping program.

RECORDS

The records described in McKelvey's report should be adopted with perhaps a few modifications on the basis of our needs. Attached herewith are copies of some of the forms used by the Geologic Division.

You will note that they are field note book size. I question whether using the reduced size is advisable. The reduced size may encourage the omission of some additional notes or explanations that we need, too many abbreviations, and perhaps writing or printing too small to be entirely legible. On page 5 of his report and attached hereto is a general information record. A recommended modification is also attached. In general the modification is merely a rearrangement of items with the addition of data which should be helpful for our information. Omitted from my form are the parts concerning the location of the highest crop exposed in the Wells formation, Rex member, etc. in relation to the trench. To gain control of the overall depositional pattern of rocks adjacent to the phosphatic intervals, I would favor measuring the best exposed stratigraphic sections of the Wells (upper 100 ft. perhaps), Rex etc., within a quarter of a mile of the trench and incorporate these data with the description of the trench section. If the adjacent rocks are not adequately exposed within a quarter of a mile, the crops of the Wells, Rex, etc. should be described at the trench site as outlined on McKelvey's information sheet. The field project geologists should assume this assignment because of its contribution to their field studies.

The time record shown on page 6 of McKelvey's report should be adopted. I hope such records will adequately reflect our anticipated efficiency.

The sample data report on page 10 is primarily for the use of the laboratories. It appears that the form material can be revised to a more condensed form, but this should be done jointly with K. P. Moore of the Casper laboratory. The sample disposition record on page 11 of McKelvey's report should be helpful. The column heading of "Date shipped to Albany" should be changed to "Date shipped to Casper."

On page 14 of McKelvey's report and attached is a table for field description of rocks. Consideration should be given to the use of a similar form to standardize our work throughout the phosphate field. The geologist describing the trench section may wish to use the field note book size forms of the rock description tables to incorporate with his final field notes. He should compile at least an adequate abstract of the section as soon as possible.

Since paleontologists are not assigned to the field mapping program, no special fossil record form may be needed. The geologist describing the rock units may utilize the table for field description of rocks to identify and comment on the fossiliferous strata. Personnel mapping the area may wish to make fossil collections for study or at least record all pertinent data to augment their geologic reports.

PREPARATION OF SECTIONS

McKelvey has presented an excellent procedure which we should follow insofar as possible. He suggests 25 copies of the abstract of the section. We should be able to reduce this to the following: copy for the field mapping party, Denver quadrangle mapping headquarters, Casper laboratory, Denver laboratory (when samples are sent for analyses), and Salt Lake City office. Six or seven copies should be adequate. The time of completion should follow McKelvey's outline.

Final report

The final report should be as informative and complete as possible. It should include at least the following:

1. Trench information sheet
2. Abstract of section with analyses
3. Table of spectrographic analyses if performed
4. Detailed description of stratigraphic sections
5. Detailed columnar section (large scale)
6. Reduced scale correlation chart showing correlations with the nearest trenches on two sides
7. Trench profile showing configuration, depth of weathering, attitude of bedding, location of contacts, faults, and other pertinent data, scale of 1 inch equals 20 feet. A geologic sketch map of approximately 1 square mile around the trench, scale 1:24,000, should be included on the trench profile illustration.

Copies of the final report should be distributed to the Washington office of Mineral Classification, quadrangle project files, mapping program headquarters in Denver, the trenching supervisor, and the Regional Office of the Mining Branch. Consideration should be given to the presentation of a copy to the Geologic Division phosphate project office. It is recommended that the report material be released to the public and industry through the circular series, open-file release, or other suitable publication.

You may wish to modify the material outlined above and undoubtedly some changes will be effected by our initial efforts. However, this may serve as a start.

The crusher and splitter seems to be some sort of an enigma. McKelvey and Bob Gulbrandsen state that the equipment was not too satisfactory. The main criticism seemed to be the time required to process the samples. They suggest moving the trench material to the Casper laboratory and let them crush and split the samples there. However, Cheney feels that since we will be collecting fewer samples, the crusher and splitter should be utilized. This would probably expedite the work of the Casper laboratory and perhaps we would prefer to make sure that all analyses

were from representative material. The bulk of our summer's work will be in the Driggs, Garns Mountain, and Irwin areas, so it is suggested that the crusher be transported there as planned and used at the trench sites where possible. If this is not satisfactory then we will find some other way to handle the trench samples. Please make sure that Henry Smith or someone knows how to run the contraption before it leaves Denver.

/s/ W. C. Gere

WGG:bmk

Attachments:
  Revised trench information sheet
  Trench illustration sheet

TRENCH NAME AND LOT NUMBER

State: County: Date:

Township and range, subdivision of section, and any other informative information concerning the location.

Field project number and name:

Project geologists:

Reason for selecting trench site:

Structure:

Time required to dig: Bulldozer--
Labor--
Time required to sample:

Length of trench: Av. depth: Strike:

Thickness of beds exposed: Strike: Dip:

Total thickness of Meade Peak member:
Upper shale member:

Nature of contact between Wells and Meade Peak member:

Nature of contact between Meade Peak member and overlying unit:

Nature of contact between underlying unit and Upper shale member:

Nature of contact between upper shale member and overlying unit:

Faults and other structural features exposed in trench:

Trench section measured and described by:

Sampled by:

Trench name and lot number:
Location:

Sketch map of the
trench profile,
scale 1" = 20'.

Sketch map of about 1 sq. mile
surrounding the trench showing the
geology and trench location or
locations, scale 1:24,000.

This page should be drafted so that copies can be included in the final trench reports. It may be necessary to shift the positions of the illustrations or draft them separately and place them in the back of the report with the graphic stratigraphic column.

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